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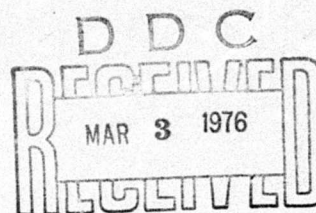


AFATL-TR-75-24

OPTIMIZATION OF FLAME FUEL DISSEMINATION PATTERNS ASSOCIATED WITH FIREBOMBS

BOMBS AND WARHEADS BRANCH
MUNITIONS DIVISION

FEBRUARY 1975



FINAL REPORT: FEBRUARY 1974 - OCTOBER 1974

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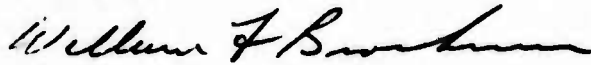
FOREWORD

This report covers research conducted during the period February 1974 to October 1974 by the Flame Fuel Laboratory, Air Force Armament Laboratory (AFATL/DLJW) in support of Project 10820302. This project was managed by Dr. Harry L. Wolfgang (DLJW).

The research was carried out at the AFATL Flame Fuel Laboratory and Burn Facility by 1st Lt Jerry D. Abrams and Capt Robert D. Epperson with assistance from D. A. Davis, Thomas G. Floyd, Andrew J. Bilbo, and Gregory A. Brinson.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER:



WILLIAM F. BROCKMAN, Colonel, USAF
Chief, Munitions Division

ABSTRACT

This report describes a research effort to find the optimum dissemination of flame agent from a firebomb. The basic approach taken was to experimentally model under laboratory conditions static dissemination patterns. This involved controlling the physical environment of the experiments and representative collection of data. A computer program was used to reduce and analyze the data. The measuring criteria for optimization were calculated in the computer analysis. These criteria were optimized to give the most effective fuel break-up and dissemination pattern. The parameters characterizing this pattern were defined, and an optimum model was constructed. Although the experimental results of this model are unique to the physical conditions of the experiments and cannot be applied directly to dynamic situations, the technique and results offer excellent relative data for the screening of possible dissemination patterns and firebomb effectiveness studies.

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SECTION I

INTRODUCTION

A major problem realized in the use of firebombs was the control of fuel breakup. The current operational environment requires flame agents that are suitable for use in a high-speed delivery mode. The requirement for an improved fuel initiated an extensive research program to develop a flame agent exhibiting physical properties which could be varied to control the breakup characteristics.^{1,2} Before a new fuel could be tailored to meet these requirements, the optimum breakup had to be determined. This report describes the results of a program developed to optimize the particle size distribution resulting from the fuel breakup.³

DISCUSSION OF THE PROBLEM

The effectiveness of a firebomb is dependent on three variables: area coverage, temperature over the area, and the duration of burn.⁴ The optimum breakup of any candidate flame agent would be that which maximizes these three variables. Each of the three variables is functionally dependent on the density (grams of fuel per square foot) and particle separation (distance between fires).

In order to find the best combination of these variables, an experimental model had to be designed such that the density and separation distance could be varied over the range of interest. The variations in the physical conditions affecting the kinetics of the fuel combustion had to be minimized.

OBJECTIVES

The principal objective of this research was to find the fuel breakup that would give the most effective temperature distribution from a firebomb. The optimum should be independent of the flame agent and environmental conditions. The results of this study will also indicate the effectiveness of a firebomb weapon. The accomplishment of these objectives required the selection of a flame agent to be burned and a number of fire array configurations to be analyzed. The fuel was selected on the basis of the research conducted by the Flame Fuel Laboratory, Air Force Armament Laboratory, Eglin Air Force Base, Florida. A blend of styrene-butadiene rubbers dissolved in benzene and gasoline (SBR) was selected. This fuel was under development as a candidate to replace the napalm B presently used in the firebomb in inventory and as a fuel for a new proximity fuze, high speed delivery bomb.

SUMMARY OF RESULTS

An optimum dissemination pattern of the flame fuel from a 100-gallon firebomb was found based on the following criteria: area coverage, mean effective temperature, and duration of the effective temperature. An experimentally determined matrix consisting of seven densities and five separation distances for each density was analyzed with each of the above mentioned dependent variables maximized. The findings of these efforts were:

The optimum area coverage from a 100-gallon firebomb with SBR fuel is 1.32×10^4 square feet with a density of 0.053 lb/ft^2 (24g/ft^2).

The optimum separation distance is 16.5 inches with a particle size of 0.088 lb (40 g).

The mean temperature above a minimum effective temperature of 150°C was predicted to be 300°C with a duration time of 200 seconds.

The predicted optimum particle size distribution was experimentally modeled with the following results: mean effective temperature of 299°C for a duration of 194 seconds. Although the results are unique to the physical conditions of these experiments and cannot be applied directly to dynamic situations, the technique and results offer excellent relative data for the screening of possible dissemination patterns and firebomb effectiveness studies.

SECTION II

SYSTEM MODELING

The dissemination pattern of the fuel from a firebomb was modeled under laboratory conditions. The model had to be representative of the particle size distribution and the separation distance of the particles. Symmetrical arrays were found with variable parameters covering the range under investigation.

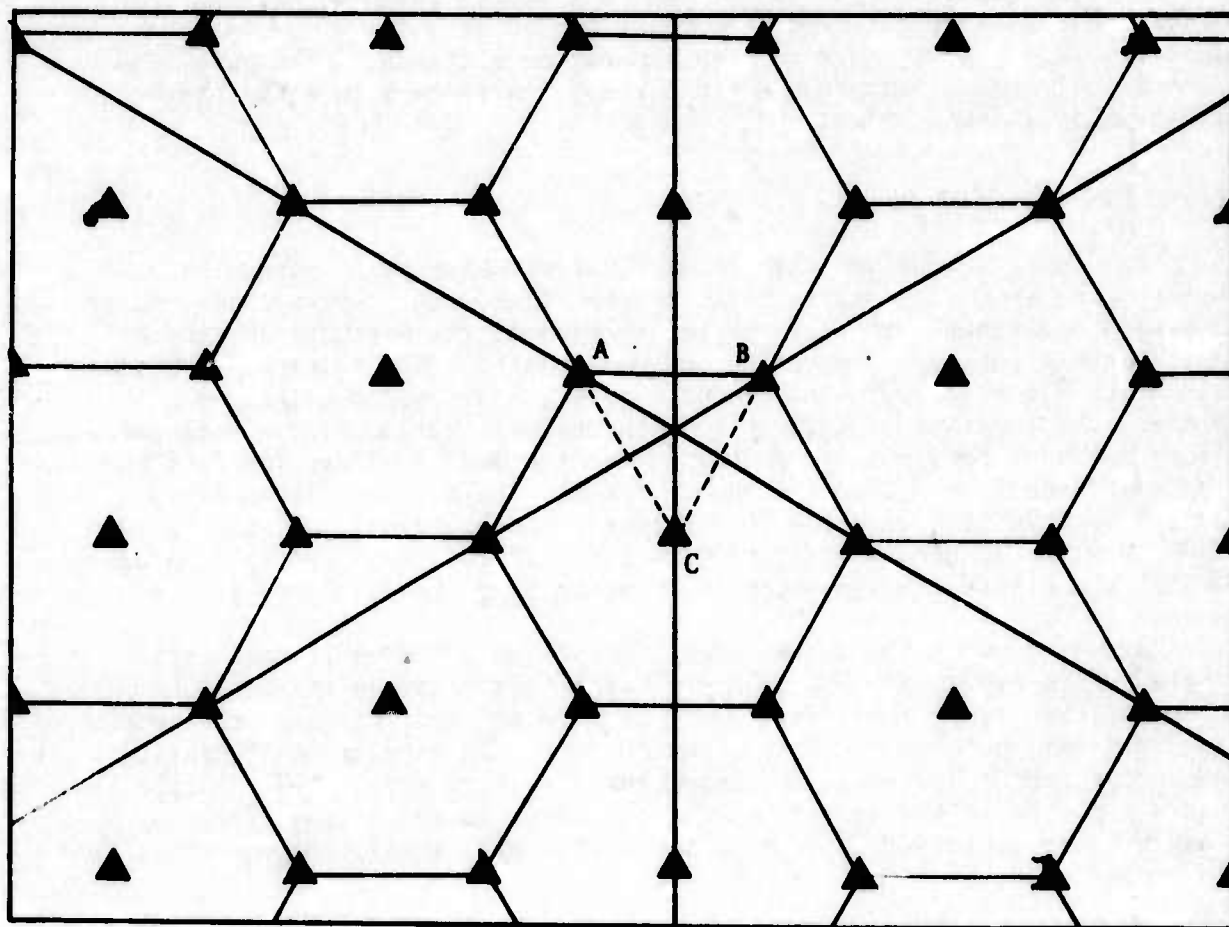
ARRAY CONFIGURATION

Five arrays of fires with geometrical symmetry were found with the distance between fires characterizing the array. Each array consisted of a grid of hexagons with fires placed at each of the vertices and centers, which gave a constant separation between samples. The hexagon was chosen since it is a good approximation of a circle that can be packed on a plane. The separation distance and density were varied over a reasonable range based on preliminary studies around the mean fuel density from the lay-down mode of a BLU-27 firebomb. The fire separation distance was varied between 12 inches and 30 inches for several densities ranging from 0.02 lb/sq ft (9 grams/sq ft) to 0.08 lb/sq ft (36 grams/sq ft). An example of the fire configuration of an array is given in Figure 1.

Symmetry was achieved by varying the size of the equilateral triangle ABC in Figure 1. The triangle was always centered on the center-point of the array; therefore, lines of fire 60° apart through the center occurred for each array. This technique achieved similar configurations about the center for the five separation distances considered. A fire was not placed at the center because of the fixed thermocouple placement. This will be discussed in Section III. The array configurations are given in Appendix A.

PARAMETER VARIATIONS

The primary concern of this study was to optimize the fuel dissemination of a firebomb. The variables affecting the criteria to be optimized were reduced to two by controlling the experiments in a burn chamber. The two variables were density and separation distance. The functional dependence of each of the parameters on the mean effective burn time and mean effective temperature had to be determined experimentally. A two-dimensional matrix over the range discussed in the previous section was constructed from the experimental results of Table 1 for each of the functions. Table 1 gives the sample size in grams for each of the experiments.



▲ Fire Location

Figure 1. Sample Fire Configuration

TABLE 1. SAMPLE SIZE IN GRAMS
FOR EACH EXPERIMENT

No. Samples	25	32	53	63	96
Separation (Inches)	30	24	18	15	12
Density (lb/ft ²) (g/ft ²)					
$\frac{0.02}{9.0}$	49	31	18	12	8
$\frac{0.03}{13.6}$	74	47	27	18	12
$\frac{0.04}{18.0}$	98	63	35	25	16
$\frac{0.05}{27.6}$	123	79	44	31	20
$\frac{0.06}{27.0}$	147	94	53	37	24
$\frac{0.07}{31.7}$	172	110	62	43	27
$\frac{0.08}{36.0}$	196	126	71	49	31

Every element in the matrix represents an experiment. It was feasible to run all 35 experiments required for the completion of the matrix; therefore, no statistical design of the experiments was necessary.

Once the matrix was completed, the functional dependence of the mean effective burn time and the mean effective temperature on the density and separation could be analyzed. The effects of each variable could be isolated. The area coverage was strictly a function of density and could be expressed analytically. With these interrelationships of the parameters known, the model could be optimized according to the definition of the optimum dissemination (maximum area coverage, maximum effective temperature, and maximum effective time).

SECTION III

EXPERIMENTAL DESIGN AND EQUIPMENT

A simple experimental model of an ideal fuel breakup pattern was developed in Section II. This section explains how the model was adapted to laboratory conditions and instrumented. The equipment used for data collection and the procedural techniques are also discussed.

DATA COLLECTION

The ultimate goal of the instrumentation was to monitor the temperature or heat over a representative area of the fire array during the entire burn time. An overall mean temperature or heat flux should be obtainable from the raw data received from selective placement of sensing devices. Physical constraints which were considered included the limited size of the chamber and the practical number of sensing devices. Relative effectiveness could be obtained from heat or temperature data. Calorimeters and radiometers were considered as possible heat sensors but were discarded due to their directional limitations. Dosimeter-type instruments measure only the total heat sensed without respect to time. Therefore, temperature measurements with thermocouples were selected as the simplest and most reproducible method of monitoring the effectiveness of the fire arrays. Since the thermocouple gives a point source temperature, it is necessary to selectively place a number of thermocouples over the area in order to obtain a representative mean temperature.

Thermocouple Configuration. The electronic data acquisition systems available had a total of 44 channels as possible inputs. This limitation necessitated a search for the most representative placement of the thermocouples to get meaningful data. The 44 channels were divided into three groups: grid, fire, and room. The grid was defined as the group of thermocouples selectively placed to monitor the temperature over the entire fire array. This group utilized 37 of the channels. Four channels were used to monitor the room temperature of the burn chamber. Two thermocouples in series were placed in each corner of the chamber, one at the top and one at the bottom of the room. The thermocouples in each corner were then connected to one of the four channels used for room temperature measurement. Three thermocouples were used to monitor fire temperatures. These were placed in the three centermost fires of each array.

Since it was desired to measure the temperature over a simulated infinite area, it was necessary to locate the thermocouples far enough away from the edge of the fire array to eliminate any possible edge effects. The fire arrays and thermocouple grid were selected such that there were always at least two rows of fires on the outside of the thermocouple grid. These configurations are shown in Appendix A.

The placement of the grid thermocouples presented a more complex problem. Since the wiring of the thermocouple grid involved a considerable amount of effort, it was desirable to have a fixed configuration that would give an excellent sampling of all the fire arrays. The complexity of the heat transfer mechanisms in the burn chamber made mathematical modeling of the temperature distribution impractical. Therefore, it was determined that the best method of sampling would be from a random placement of the thermocouples over the entire area. Several different grids were considered and evaluated by an empirical trial and error method until a grid was selected which appeared to give a satisfactory sampling of the area.

Since the fire arrays used are symmetrical, many points within each array are theoretically equivalent. The hexagons in the arrays can be divided into six equilateral triangles with fires at each of the vertices as shown in Figure 2. The area of triangle ABC in this figure is equivalent to the area inside any triangle connecting any three fires in an array. This triangle can be further subdivided into the six triangles numbered 1 through 6, as shown in the figure. Each of these triangles is a truly unique area, that is, no two points within the triangle are equivalent and every point within the triangle is equivalent to a corresponding point within any of the other congruent triangles. If the position of each thermocouple is considered with respect to the nearest fire, the location of every thermocouple can be represented by a point in triangle 1 (or similarly any of the triangles numbered 1 through 6). The thermocouple grids considered were evaluated by locating each thermocouple in triangle 1 to determine if the sampling was random and representative of the entire area.

The thermocouple grid selected is shown in Figure 3. This configuration gave an excellent coverage of the unique area for each of the fire arrays without having to move the thermocouples. The sampling for each of the arrays is shown in Figure 4. The dots in the triangle represent single thermocouples while the circled dots and slashed dots represent two and three thermocouples, respectively. One thermocouple was placed at the unique point where the six triangles in triangle ABC of Figure 2 intersect. The thermocouple and fire configurations are given in Appendix A.

Monitoring Equipment and Burn Facility. A specially equipped burn chamber was electronically instrumented to carry out the experiments necessary for this study. Equipment readily available was adapted to the needs dictated by these experiments. A chamber designed for the purpose of studying flame agents and incendiaries was modified to accommodate the tests.

Two data acquisition systems were available for use in the monitoring of the temperature distribution over the fire arrays. System I was a 24-channel data collection unit with a variable sampling rate and controlled by a Nova 1210 computer. System II was a 20-channel unit with 100-

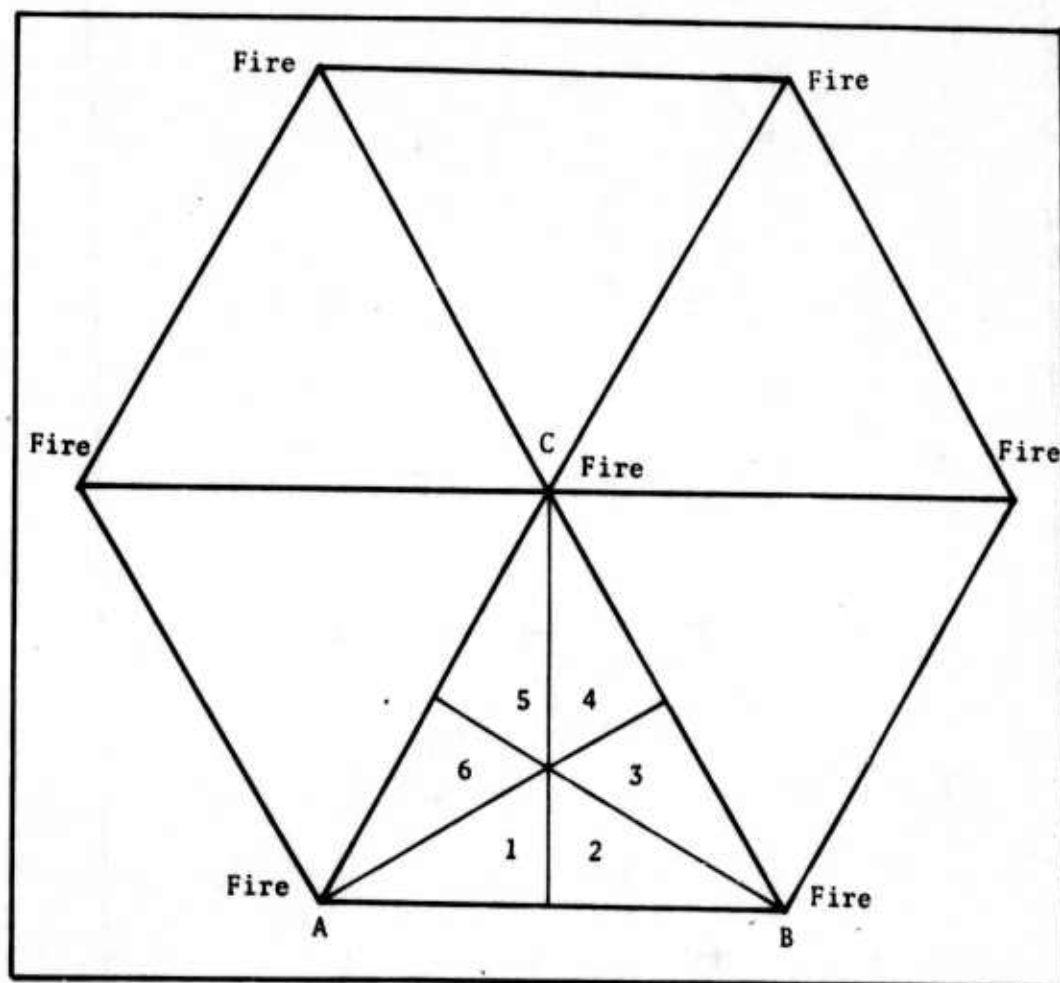
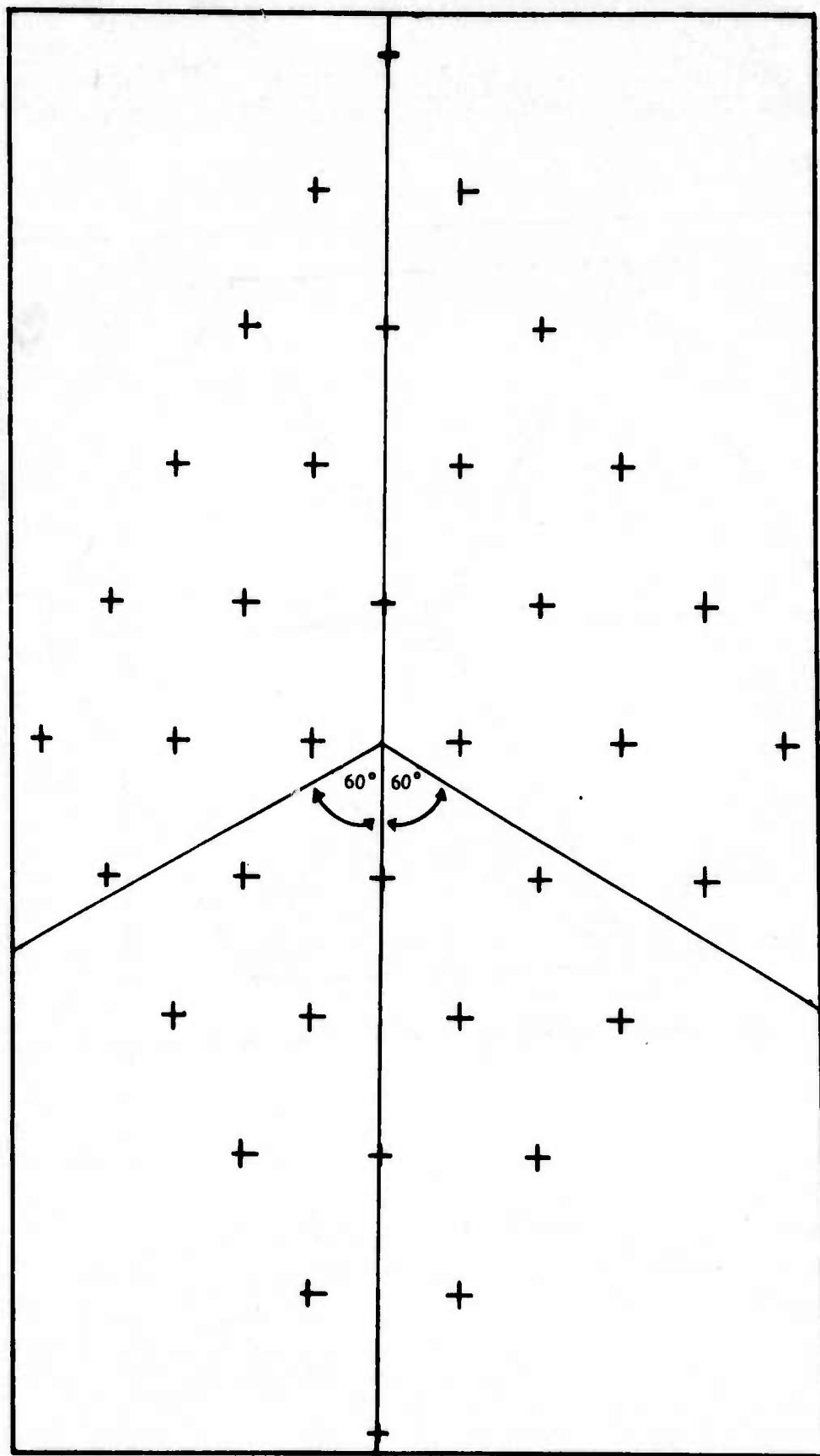
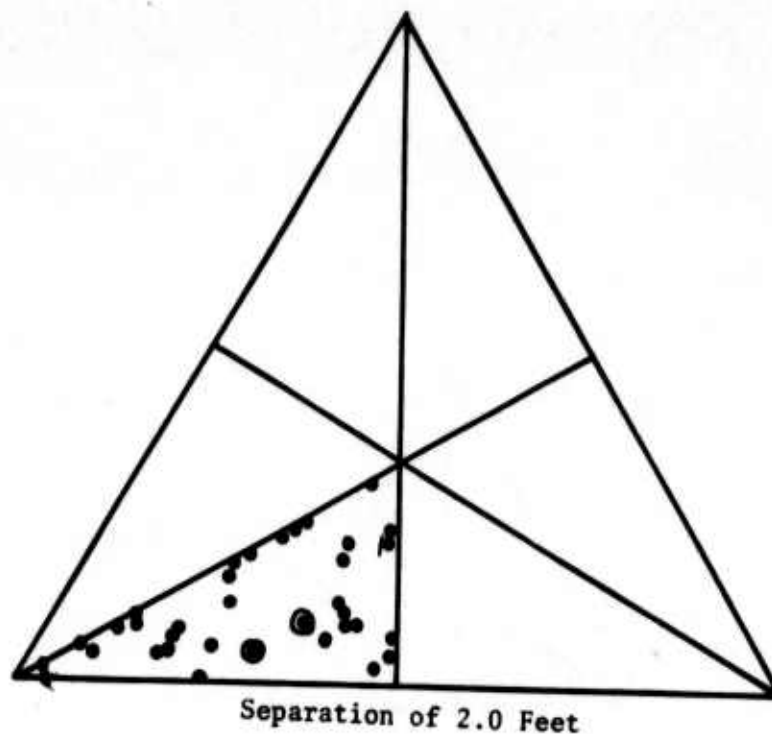


Figure 2. Divided Hexagon



Scale 1" = 0.5'

Figure 3. Thermocouple Grid



Scale 1" = 0.5'

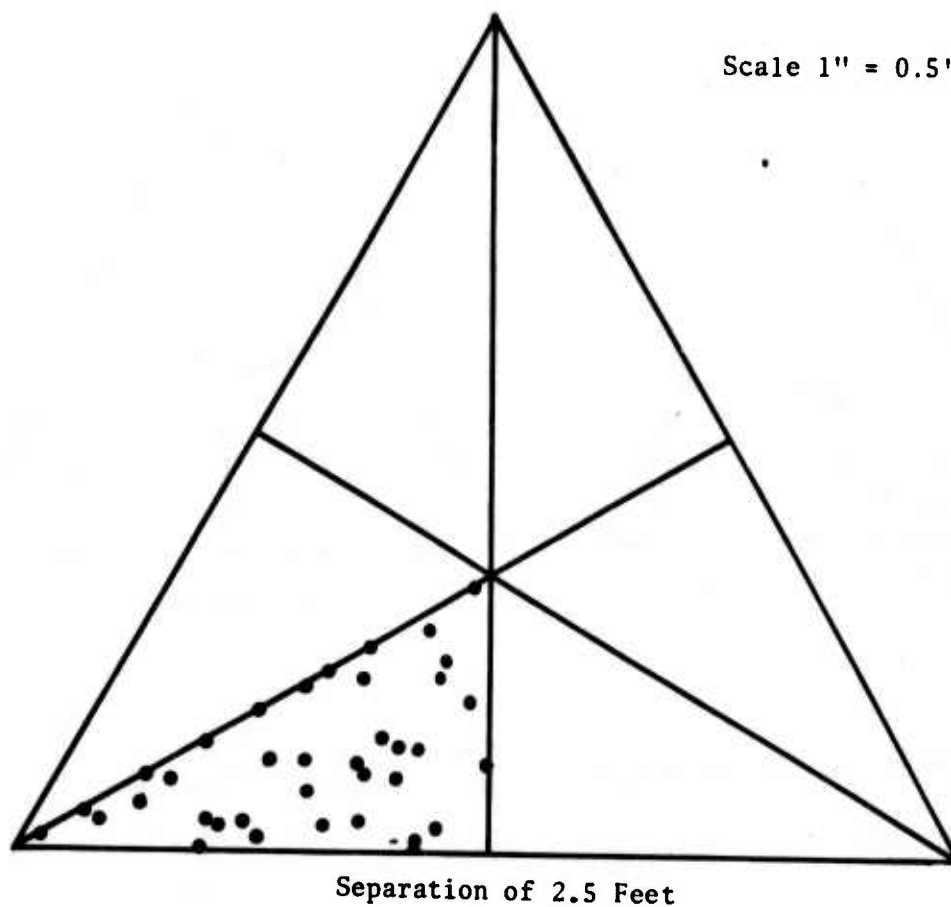
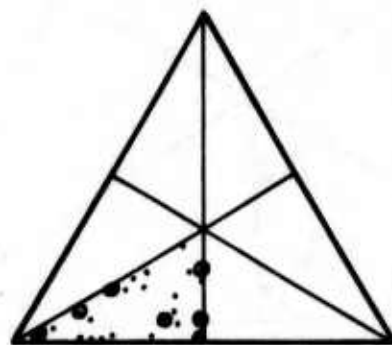
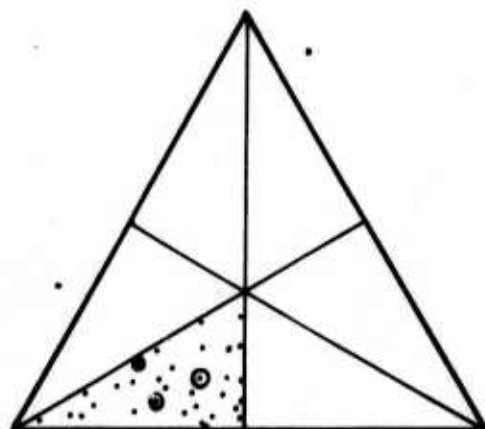


Figure 4. Thermocouple Sampling Patterns

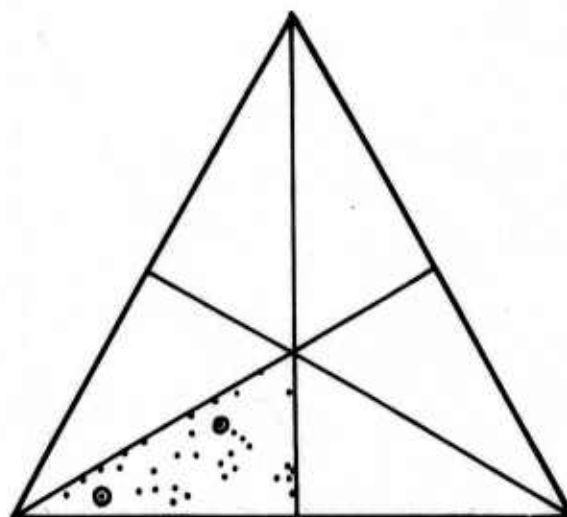


Separation of 1 Foot

Scale 1" = 0.5'



Separation of 1.5 Feet



Separation of 1.5 Feet

Figure 4. Thermocouple Sampling Patterns (Concluded)

millisecond sampling rate. Both systems were built by Scientific Instruments Research. Seven-track Kennedy Recorders were used to record the data on magnetic tape. The two collection systems were synchronized by a common on-off switch located near the burn chamber. The combined 44 channels were wired to Chromel-Alumel thermocouples selectively placed in the chamber. The data acquisition systems are shown in Figures 5 and 6.

A 19 x 19-foot burn chamber with insulated walls was used as a controlled environment to carry out the experiments. A Dexon floor was installed with all the wiring beneath the floor and the thermocouples fixed in position on the surface. An asbestos covering was placed on top of the flooring with the thermocouple junctions three to four inches above the surface. The chamber was equipped with a refrigeration unit capable of maintaining temperatures as low as -30°C . An air circulation system consisting of an inlet and exhaust fan prevented oxygen starvation by displacing the by-products of the combustion with fresh air. Figure 7 shows the chamber immediately before a burn with the samples in position. The fixed thermocouple grid can also be seen in Figure 7.

The combined effect of the errors occurring from the equipment was well within the accuracy of the experimental procedure. An estimated accuracy within ± 5 percent from combined equipment and experimental error was determined. This was well within a set allowable error of ± 10 percent.

EXPERIMENTAL PROCEDURES

All experiments were basically the same, therefore, a general procedure was outlined for the preparation and running of the two types of experiments (ambient and cold weather). The initial sample handling was the same for all tests.

Sample Preparation. The flame agent selected for the study was a blend of Styrene-butadiene Rubber (29 percent), benzene (27.3 percent), and gasoline (43.7 percent). The selection was based on the results of a screening program by the Air Force Armament Laboratory. This fuel was readily available since it was the primary agent being considered for a high-speed, proximity fuze firebomb and was prepared in-house. The fuel blend was held constant throughout the program; therefore, the results should be relative to each experiment and independent of the fuel.

The fuel samples ranged in size from 8 to 200 grams. Polyethylene zip-top bags were used to contain the samples. The bags were filled by two techniques depending on the size of the fuel sample. Samples between 100 and 200 grams were filled directly from a 5-gallon Jerry can with a 1-inch ball valve for control. The accuracy was ± 1 gram. The smaller samples were filled with syringes, and the accuracy was ± 0.5 gram. Two different size bags were used: 4 x 4-inch bags were used for the smaller samples, and 6 x 6-inch bags were used for the larger samples. The time



Figure 5. Data Acquisition System I

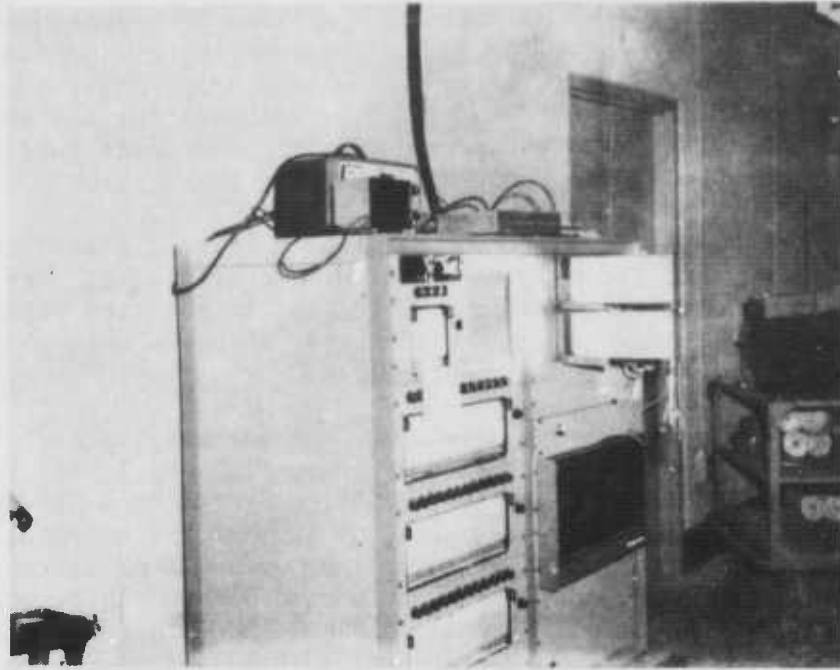


Figure 6. Data Acquisition System II

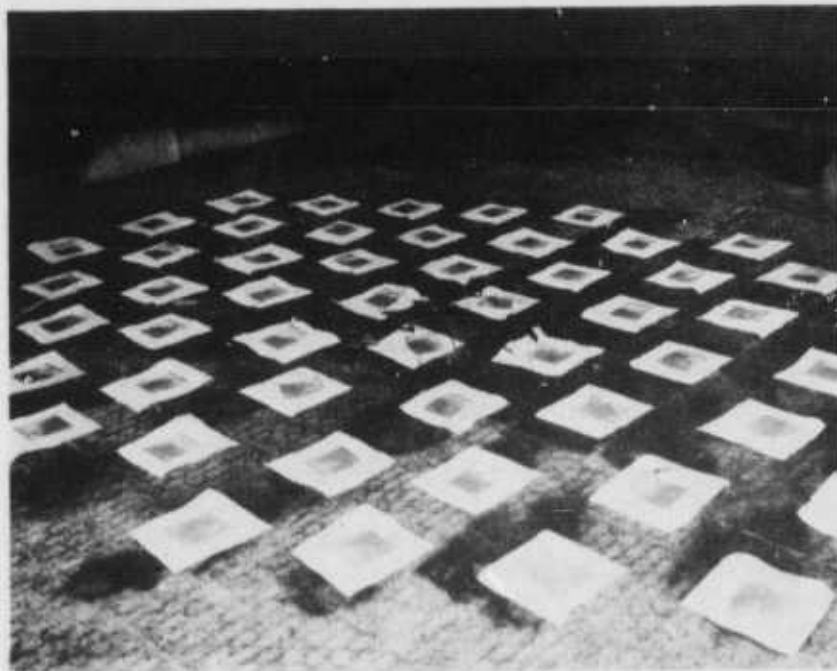


Figure 7. Burn Chamber

required to prepare the samples was held at a minimum to reduce possible errors resulting from lost volatiles during the handling of the fuel. The prepared samples were stored in air-tight ammunition cans until they were burned. The storage time was held to less than 24 hours for the ambient experiments. The samples used in the cold weather study were cold soaked for at least 24 hours below the temperature under investigation.

Ambient Burns (25°C to 30°C). The complete matrix of experiments was run with the initial conditions in the burn chamber held at ambient (25°C to 30°C). The fire positions were identified, and an asbestos paper square was placed on each location. The three fire thermocouples were placed over the respective fires for the array being burned.

The two data collection systems were checked and calibrated before each experiment. Each system was loaded with magnetic tapes, and the control was switched to a common on-off switch located next to a view port near the burn chamber. A sample was placed on each of the asbestos papers. At this time the inlet and exhaust fans for the burn chamber were turned on. Five personnel were needed to start each experiment. Three persons were used to light the fires with propane torches, one stayed outside the chamber for safety purposes, and the fifth controlled and monitored the data acquisition. Electronic timers were used to measure the ignition time and burn times.

The data collection systems and the timers were started when the first fire was ignited. The ignition time ranged between 20 and 40 seconds depending on the number of fires. This variation was negligible since the total burn time was always over 10 minutes. The times the first and last fires burned out were recorded. Good reproducibility of these times indicated the burning mechanism did not vary enough to affect the results.

At the end of each burn the chamber was allowed to cool while the data was unpacked, and the equipment was prepared for the next experiment. The data was stored on two magnetic tapes until it could be reduced on the CDC 6600 computer.

Cold Weather (0°C and -30°C). The cold weather experiments were carried out by procedures similar to the ambient runs. The only variations occurred in the chamber preparation and the fire ignition. The temperature in the burn chamber was stabilized at the temperature being investigated. The refrigeration unit was turned on at least 24 hours before a scheduled experiment. This allowed time for the walls to reach a stable temperature so that the cooling unit could hold the chamber temperature close to the set value with minimum fluctuation. The only changes in the ignition procedure were the time the fans were turned on and the duties of the person located outside the burn chamber. The cooling unit was turned off after all the samples had been placed in the chamber. The exhaust and inlet fans were turned on when the first fire

was ignited. The outside man opened the vent for the exhaust fan and the door for the inlet fan when the personnel entered the chamber to begin igniting the fires. The procedure was the same as the ambient procedure for the remaining portion of the experiment. At the end of the burn the inlet and exhaust vents were closed, and the cooling unit was turned back on. The chamber was lowered to the temperature being studied and allowed to stabilize. This time varied according to the amount of temperature difference between the set value and the maximum temperature resulting from the burn.

SECTION IV

ANALYSIS OF DATA

The data collected had to be converted to a form that could be analyzed thoroughly. A computer program was written in Fortran IV and used with a CDC 6600 computer to reduce the data. Once the data had been reduced to a workable form, the optimum combination of parameters was found. This section discusses the computer reduction of the data and the techniques used to optimize the variables.

COMPUTER REDUCTION OF DATA

The raw data consisted of millivolt readings taken from each thermocouple at 0.1-second intervals. This information was stored on two magnetic tapes in binary for each experiment. Tape I from system I was a recording of the first 24 thermocouples, and Tape II from system II contained the data from the remaining 20 thermocouples. The information was placed on the tapes in 5-second records with each record representing 50 scans of each thermocouple. All experiments contained at least 120 records.

A computer program was written in Fortran IV to unpack the data from the tapes and reduce it to a meaningful form. The program is given in Appendix B. A step-by-step summary of the operations carried out by the program follows:

The millivolt readings from the thermocouples were converted to degrees centigrade by the conversion factors: 1 millivolt = 24.6°C and 1 millivolt = 10.24 in binary coded digits.

All channels were averaged over each 5-second record with the average treated as the reading at the beginning of the time interval. This smoothed the curves and reduced the data points to 120 for each point monitored.

The 37 values for the grid thermocouples were averaged for each of the 120 time steps. The same operation was carried out for the three fire values and the four room values. A fourth average combined the grid and fire values. These averages along with the averages of the 44 channels were stored in a 120 x 48 matrix. The first 44 columns represent the actual thermocouples monitored. Columns 45, 46, 47 and 48 represent the average of the grid, grid plus the fire, fire and room, respectively.

A minimum effective temperature of 150°C was selected. This baseline was picked as the minimum since very little target destruction would be expected below this temperature.

A numerical integration of all 48 curves was carried out over the 120 time steps. The trapezoidal method was used. The results gave a relative heat measurement which could be used for comparison.

A search was conducted for the maximum temperature of each thermocouple and the time this maximum occurred. The same values were determined for the four averages also.

The baseline of 150°C was established, and the portion of each curve above this baseline was identified.² This part of the curve was numerically integrated for each of the 48 curves.

A time-averaged temperature was calculated for the entire curve and the effective region of each curve.

Each of the 48 curves was plotted by the computer. These plots were used for fast validity checks on the data.

A map of the thermocouple grid was also plotted by the computer at various time intervals. The temperature distribution could easily be seen from these maps.

The computer program had many checks incorporated in the logic. Errors encountered in the handling of magnetic tape were routed through specific subroutines for special treatment in order to salvage data. The option of throwing out bad data resulting from thermocouple or electronic equipment failure was included in the program. This minimized the rerunning of experiments where only an insignificant fraction of the data was bad. A complete listing of the program named Particle Size Distribution Study (PSDS) is given in Appendix B.

EXPERIMENTAL RESULTS

Each experiment was run at least three times to assure the validity of the data. Each bit of information from the reduction of the data was tabulated by the computer for each experiment. An example of this table is given in Table 2. The three tables from each like experiment showed excellent reproduction and were combined to give a fourth table of averages. The data needed for optimization was then extracted from the averaged results.

The criteria defined earlier for an optimum dissemination pattern were maximum mean effective temperature, maximum mean time above the minimum effective temperature and the maximum area coverage. The data describing these criteria were taken from the average tables and tabulated in Tables 3 and 4. Table 3 is the mean effective temperature for the thermocouple grid, and Table 4 is the mean time above the minimum effective temperature for the grid thermocouples. Graphs were constructed

TABLE 2. SAMPLE OUTPUT OF COMPUTER PROGRAM

CHANNEL	TOTAL AREA DEG-SEC	HEAT OUTPUT AVE DEG C	APCA DEG-SEC	MAXIMUM AVE DEG C	HEAT START SEC	END SEC	OUTPUT DELTA SECONDS	TIME MAX SECONDS	TIME AT MAX SECONDS	MAXIMUM TEMP DEG C	MAXIMUM TEMP DEG C
1	35656	159.	77460	344.	35.	2440.	205.	105.	105.	445.	445.
2	72049	120.	47906	342.	35.	195.	170.	170.	170.	445.	445.
3	102423	175.	82609	330.	35.	240.	220.	105.	105.	445.	445.
4	192743	180.	87377	361.	35.	250.	180.	105.	105.	445.	445.
5	107803	161.	51274	285.	35.	190.	140.	105.	105.	445.	445.
6	96677	121.	44173	287.	35.	170.	140.	105.	105.	445.	445.
7	65336	103.	47804	290.	35.	190.	165.	105.	105.	445.	445.
8	72761	151.	65215	310.	35.	180.	175.	105.	105.	445.	445.
9	37503	132.	54258	310.	35.	190.	160.	105.	105.	445.	445.
10	64634	108.	39173	344.	35.	220.	190.	105.	105.	445.	445.
11	108654	151.	86947	373.	35.	220.	220.	105.	105.	445.	445.
12	108654	133.	86554	373.	35.	195.	220.	105.	105.	445.	445.
13	66061	110.	51591	314.	35.	195.	180.	105.	105.	445.	445.
14	72355	133.	51642	314.	35.	210.	180.	105.	105.	445.	445.
15	72355	115.	66535	328.	35.	210.	180.	105.	105.	445.	445.
16	92523	115.	61158	352.	35.	210.	180.	105.	105.	445.	445.
17	33674	106.	55538	352.	35.	210.	180.	105.	105.	445.	445.
18	78004	130.	55538	352.	35.	210.	180.	105.	105.	445.	445.
19	85514	141.	61408	307.	35.	210.	180.	105.	105.	445.	445.
20	69472	116.	67626	290.	35.	210.	180.	105.	105.	445.	445.
21	12683	113.	91277	405.	35.	210.	180.	105.	105.	445.	445.
22	33788	113.	46008	391.	35.	210.	180.	105.	105.	445.	445.
23	62695	110.	43844	277.	35.	210.	180.	105.	105.	445.	445.
24	72717	111.	47466	285.	35.	210.	180.	105.	105.	445.	445.
25	66507	111.	50206	285.	35.	210.	180.	105.	105.	445.	445.
26	105060	115.	45862	296.	35.	210.	180.	105.	105.	445.	445.
27	74789	125.	43300	438.	35.	210.	180.	105.	105.	445.	445.
28	58636	125.	52672	438.	35.	210.	180.	105.	105.	445.	445.
29	103700	115.	79205	348.	35.	210.	180.	105.	105.	445.	445.
30	93295	115.	56435	348.	35.	210.	180.	105.	105.	445.	445.
31	22502	115.	71692	326.	35.	210.	180.	105.	105.	445.	445.
32	23092	115.	0	0.	35.	210.	180.	105.	105.	445.	445.
33	80864	137.	0	0.	35.	210.	180.	105.	105.	445.	445.
34	82089	137.	57173	309.	35.	210.	180.	105.	105.	445.	445.
35	97197	162.	57820	313.	35.	210.	180.	105.	105.	445.	445.
36	25298	142.	71904	327.	35.	210.	180.	105.	105.	445.	445.
37			0	0.	35.	210.	180.	105.	105.	445.	445.
38			0	0.	35.	210.	180.	105.	105.	445.	445.
39			0	0.	35.	210.	180.	105.	105.	445.	445.
40			0	0.	35.	210.	180.	105.	105.	445.	445.
41			0	0.	35.	210.	180.	105.	105.	445.	445.
42			0	0.	35.	210.	180.	105.	105.	445.	445.
43			0	0.	35.	210.	180.	105.	105.	445.	445.
44			0	0.	35.	210.	180.	105.	105.	445.	445.
45			0	0.	35.	210.	180.	105.	105.	445.	445.
46			0	0.	35.	210.	180.	105.	105.	445.	445.
47			0	0.	35.	210.	180.	105.	105.	445.	445.
48			0	0.	35.	210.	180.	105.	105.	445.	445.
AVE OF ALL TC'S ABOVE											
AVE	56985.	319.	56985.	319.	23.	202.	179.				
FOR	56986.	319.	56986.	319.	23.	202.	179.				
TC'S											
AVE											
TEMP											

TABLE 3. MEAN EFFECTIVE GRID
TEMPERATURES VERSUS DENSITY

Mean Grid Temperature = Average of 37 Thermocouples in the Grid (°C)

Density (Grams/ft ²)	Separation Distance (Inches)				
	12	15	18	24	30
9.0	233	218	198	182	172
13.6	283	250	227	207	186
18.0	301	288	260	225	211
22.6	340	319	271	254	250
27.0	364	341	295	269	268
31.7	382	355	327	291	316
36.0	406	370	341	320	319

TABLE 4. AVERAGE TIME GRID TEMPERATURE
WAS ABOVE 150°C

$\Delta t(\text{sec}) = \text{Time above } 150^\circ\text{C}$

Density (Grams/ft ²)	Separation Distance (Inches)				
	12	15	18	24	30
9.0	78	83	88	92	108
13.6	107	125	140	172	188
18.0	137	160	178	218	263
22.6	160	178	210	252	262
27.0	178	192	233	273	275
31.7	182	202	258	260	293
36.0	183	233	275	278	305

from these tables to illustrate the functional dependence of the criteria on density and sample separation. Figure 8 graphically illustrates the relationships of the mean effective temperature over the thermocouple grid with the density and sample separation. Figure 9 is a similar plot for the mean time above the minimum effective temperature. These figures can be used to describe the effectiveness of an actual SBR firebomb behavior by correlating the experimentally determined density and particle size with the corresponding combination from this study. The SBR fuel should be the same blend as that used in this program for the best correlation, but other thicknesses and hydrocarbon fuels should yield similar results.

A representative sample of the experiments was run at lowered temperatures. The results of these experiments indicated the behavior of the fuel at cold weather conditions. Table 5 compares these results with the ambient runs. The trends are the same with the only difference being an offset of the baseline approximately equivalent to the temperature differential between the ambient temperature and the lowered temperature. The ignition time was increased slightly which was to be expected since the samples had been cold-soaked.

OPTIMIZATION OF THE PARAMETERS

The general objective in any optimization is to choose a set of values of the independent variables, subject to various restrictions, which will produce the desired optimum response for the particular problem under examination. The purpose of this section is to explain the methods used to accomplish this objective from the experimental results given in the previous section. Tables 3 and 4 are matrices representing black box models of the system to be optimized. A black box model is defined as a model constructed by varying controlling parameters of a physical process and recording the results experimentally.⁵

The criteria on which the optimum is based was divided into two systems with competing influences. The area coverage is a decreasing function of density; that is, the area coverage decreases as the density increases. The mean effective temperature over the grid thermocouples increases as the density increases, therefore a system was considered for these opposing influences. An optimum density was found that would give the best combination of these criteria. The area coverage is independent of the sample separation. The functional relationship of the area coverage and the density is given by Table 6 and Figure 10. The second system consisted of the mean effective temperature and the mean time above the minimum effective temperature as the conflicting influences. This system was expressed as a function of sample separation for each density. The separation giving the best combination of these criteria was found for the optimum density.

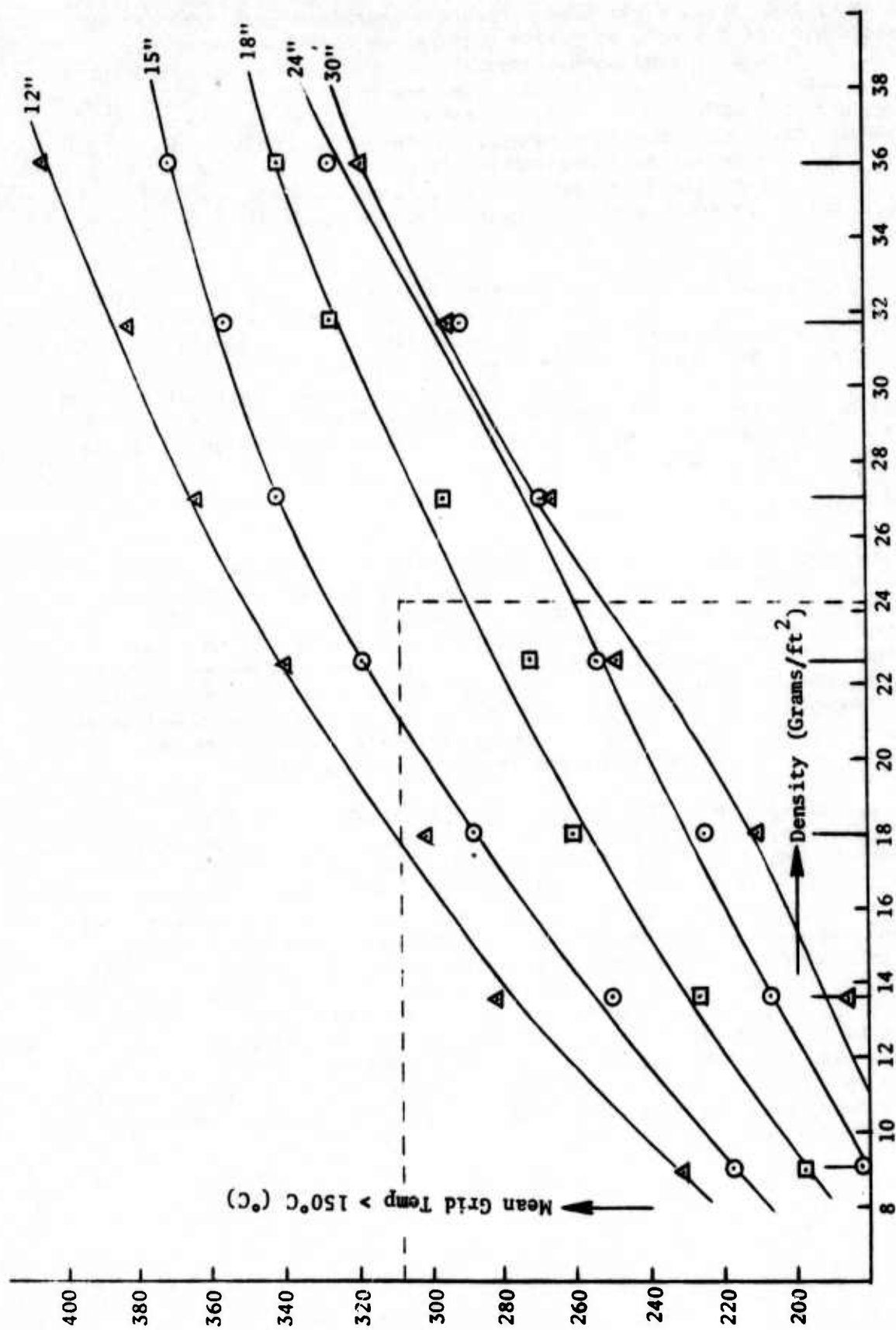


Figure 8. Mean Grid Temperature Above 150°C Versus Density

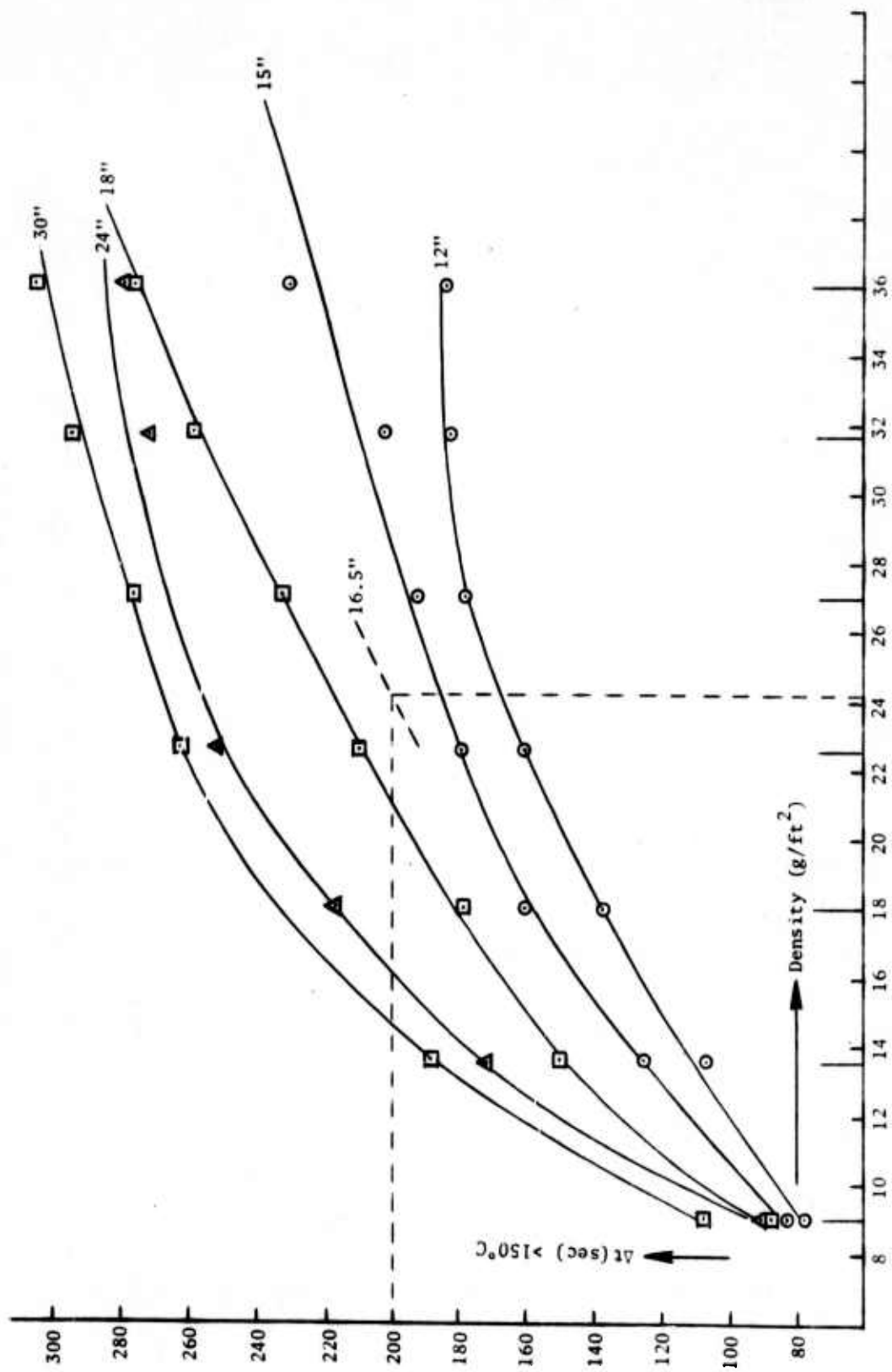


Figure 9. Mean Time Grid Above 150°C Versus Density

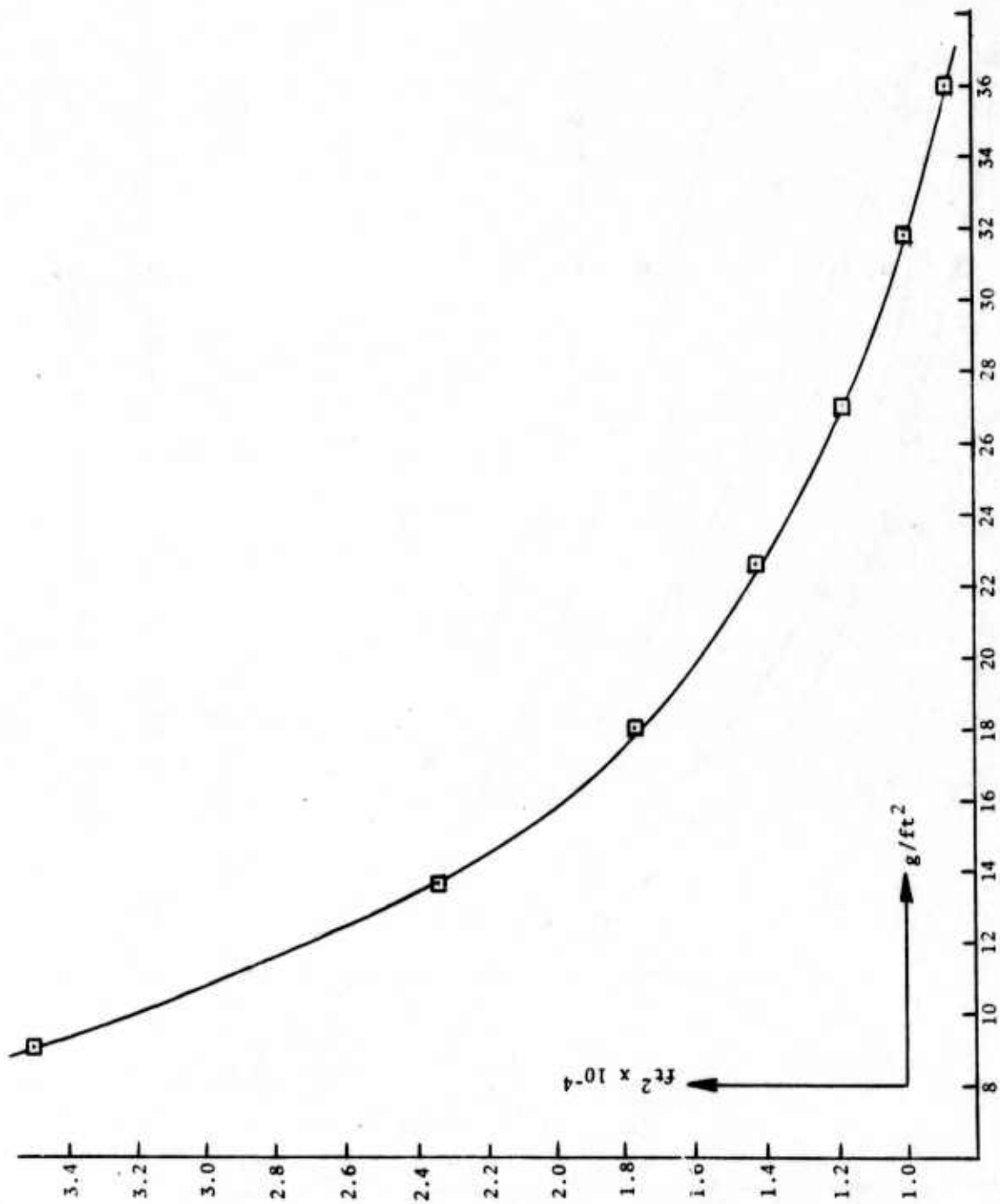


Figure 10. Area Coverage Versus Den

TABLE 5. COMPARISON OF LOWERED TEMPERATURES
TO AMBIENT FOR SPECIFIED
DENSITIES AND SEPARATION DISTANCES

Density	Separation Distance (Inches)			
	18	18	24	24
	Mean Grid Temp > 150°C	Mean Time > 150°C	Mean Grid Temp > 150°C	Mean Time > 150°C
22.6				
Ambient	271	210	247	252
0°C	256	222	214	282
27.0				
Ambient	295	233	245	293
0°C	248	272	205	323
31.7				
Ambient	326	256	343	230
0°C	280	300	249	268

TABLE 6. AREA COVERAGE VERSUS DENSITY
(100-GALLON BOMB)

Density (Grams/ft ²)	Area Coverage (Ft ²)
9.0	3.5 x 10 ⁴
13.6	2.34 x 10 ⁴
18.0	1.77 x 10 ⁴
22.6	1.41 x 10 ⁴
27.0	1.18 x 10 ⁴
31.7	1.00 x 10 ⁴
36.0	0.883 x 10 ⁴

The approach used to optimize the system of conflicting influences consisted of converting the data such that the two influences are measured on similar scales. This was accomplished by basing the criteria on the minimum and expressing the results graphically as the ratio of the minimum to the particular experimental results versus the independent variable.

The first system to be optimized was the area coverage and mean effective temperature versus density. The system was analyzed for several sample separations, and the final result was taken to be the average. Tables 7 and 8 express this system as two matrices with the indicators measured on similar scales. Each column represents the results for a particular separation distance. The same column of each matrix is plotted versus density on a common graph in Figures 11 and 12. The point of intersection should give the optimum density. This point represents the minimum ratio of the lowest experimental value of the mean effective temperature and also the minimum ratio of the smallest area coverage to the area coverage. Therefore, the density at the particular point will give the maximum area coverage and the maximum mean effective temperature. The average over the various sample separations gave an optimum density of 24 grams per square foot (0.053 lb/ft^2).

The second system was used to optimize the sample separation. The competing influences were mean effective temperature and mean time above a minimum effective temperature. A matrix of each of the conflicting influences was constructed with the indicators based on the ratio of the minimum to the particular measurement. The matrices are given by Tables 9 and 10. These matrices were treated in the same manner as those of system 1. Common rows of each matrix were plotted versus sample separation on the same graphs. These graphs are given in Figures 13 to 18. The intersection of the curves occurred at the separation distance which gave the maximum mean effective temperature and maximum mean time above a minimum effective temperature. The average of the results obtained for the different densities was concluded to be the optimum sample separation. This result was 16.5 inches.

The optimum dissemination of a flame agent with physical properties similar to the SBR blend used in this study (or Napalm B) would give a mean density of 24 grams/ft^2 (0.053 lb/ft^2) over an area of $13,300 \text{ ft}^2$ with fuel particle separation averaging 16.5 inches. The mean particle size for this dissemination was found from Figure 19 to be 40 grams (0.088 lb). A theoretical relative effectiveness of this dissemination can be extracted from Figures 8 and 9 based on these parameters. This predicted effectiveness criteria for the experimental conditions of this study were a mean effective temperature of 300°C for a mean time of 200 seconds.

TABLE 7. MEAN EFFECTIVE TEMPERATURE BASED ON THE
MINIMUM EXPERIMENTAL VALUE
FOR EACH SEPARATION DISTANCE

Density (Grams/ft ²)	Separation (Inches)				
	30	24	18	15	12
9.0	1.0	1.0	1.0	1.0	1.0
13.6	0.92	0.88	0.87	0.87	0.82
18.0	0.81	0.81	0.76	0.76	0.77
22.6	0.69	0.72	0.73	0.68	0.68
27.0	0.60	0.68	0.67	0.69	0.64
31.7	0.54	0.55	0.61	0.61	0.61
36.0	0.54		0.58	0.60	

TABLE 8. AREA COVERAGE BASED ON THE
MINIMUM AREA COVERED

Density (Grams/ft ²)	Minimum Area/Area
9.0	0.25
13.6	0.38
18.0	0.50
22.6	0.63
27.0	0.75
31.7	0.88
36.0	1.00

TABLE 9. MEAN EFFECTIVE TEMPERATURE BASED ON THE
MINIMUM EXPERIMENTAL VALUE FOR EACH DENSITY

Separation (Inches)	Density (Grams/ft ²)						
	9	13.6	18	22.6	27	31.7	36
30	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	0.95	0.90	0.94	1.01	1.09	0.92	0.98
18	0.87	0.81	0.81	0.92	0.96	0.97	0.94
15	0.79	0.74	0.73	0.78	0.84	0.89	0.86
12	0.74	0.66	0.70	0.74	0.78	0.83	0.88

TABLE 10. MEAN TIME ABOVE 150°C BASED
ON THE MINIMUM EXPERIMENTAL VALUE FOR EACH DENSITY

Separation (Inches)	Density (Grams/ft ²)						
	9	13.6	18	22.6	27	31.7	36
30	0.72	0.57	0.52	0.61	0.65	0.62	0.62
24	0.85	0.62	0.63	0.63	0.61	0.79	0.68
18	0.89	0.71	0.77	0.76	0.76	0.71	0.69
15	0.94	0.86	0.86	0.90	0.93	0.90	0.82
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00

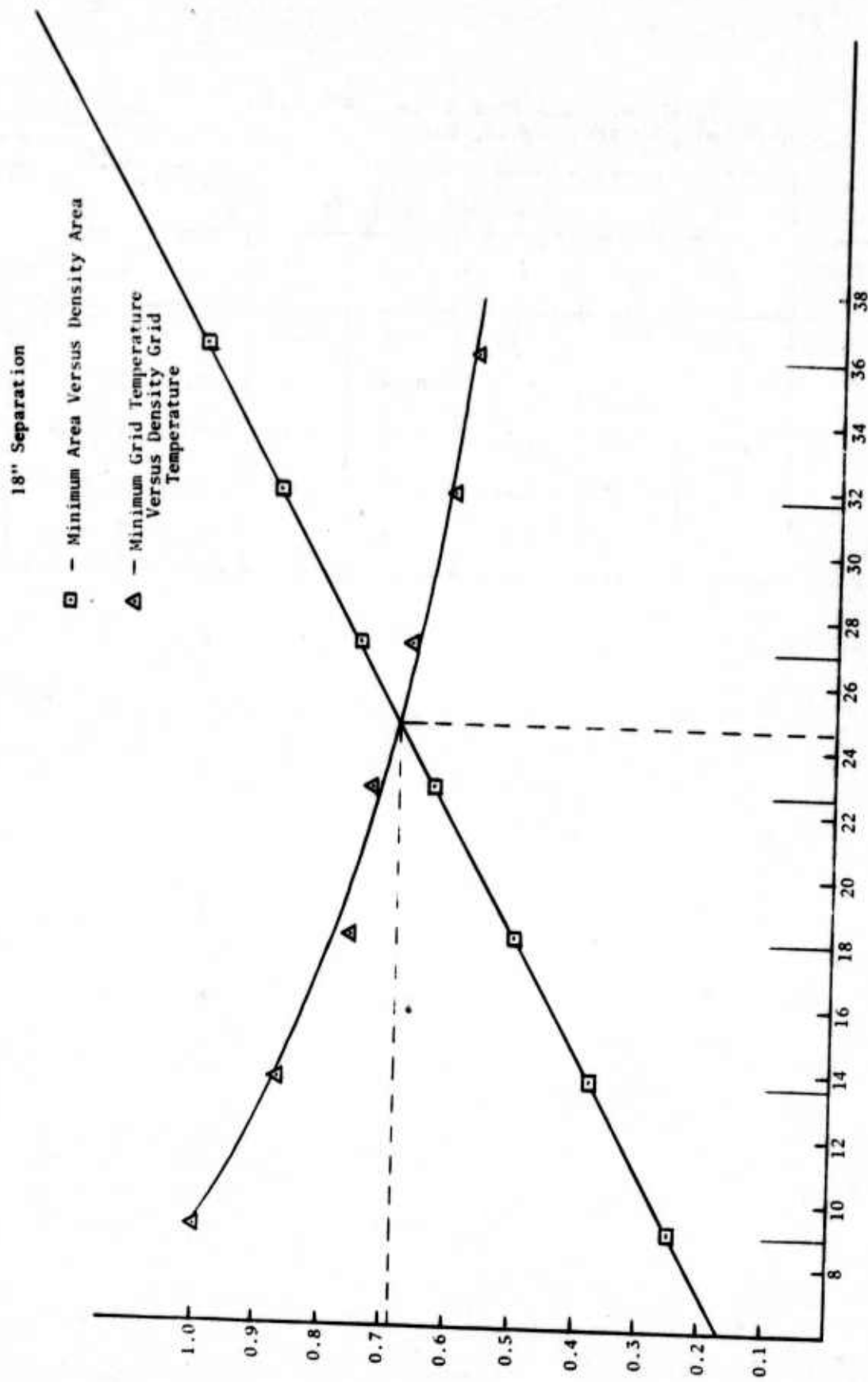


Figure 11. 18-Inch Separation With Area Coverage and Mean Effective Grid Temperature as the Competing Influences

15" Separation

□ - Minimum Area Versus Density Area

△ - Minimum Grid Temperature Versus Density Grid Temperature

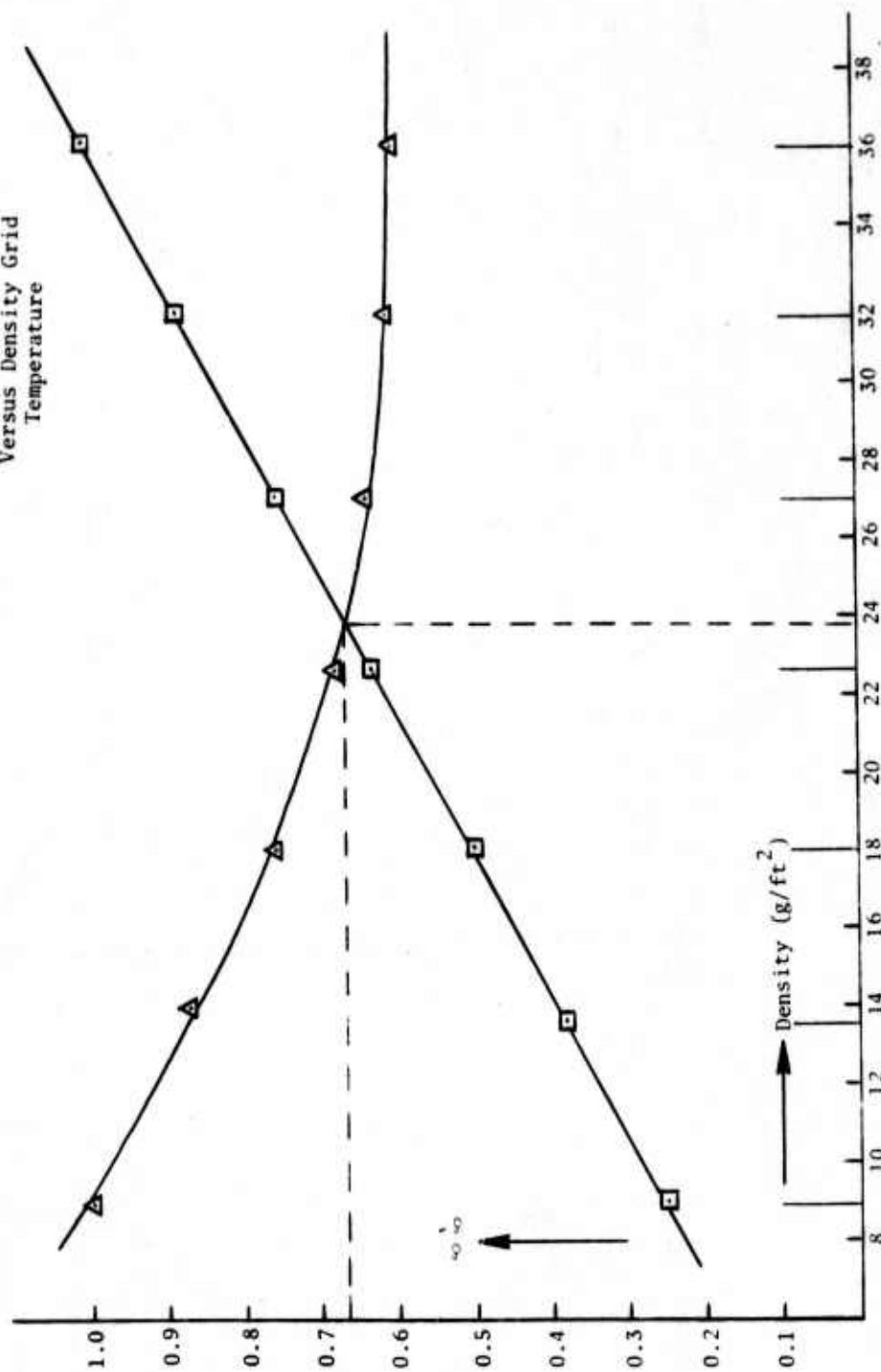


Figure 12. 15-Inch Separation With Area Coverage and Mean Effective Grid Temperature as the Competing Influences

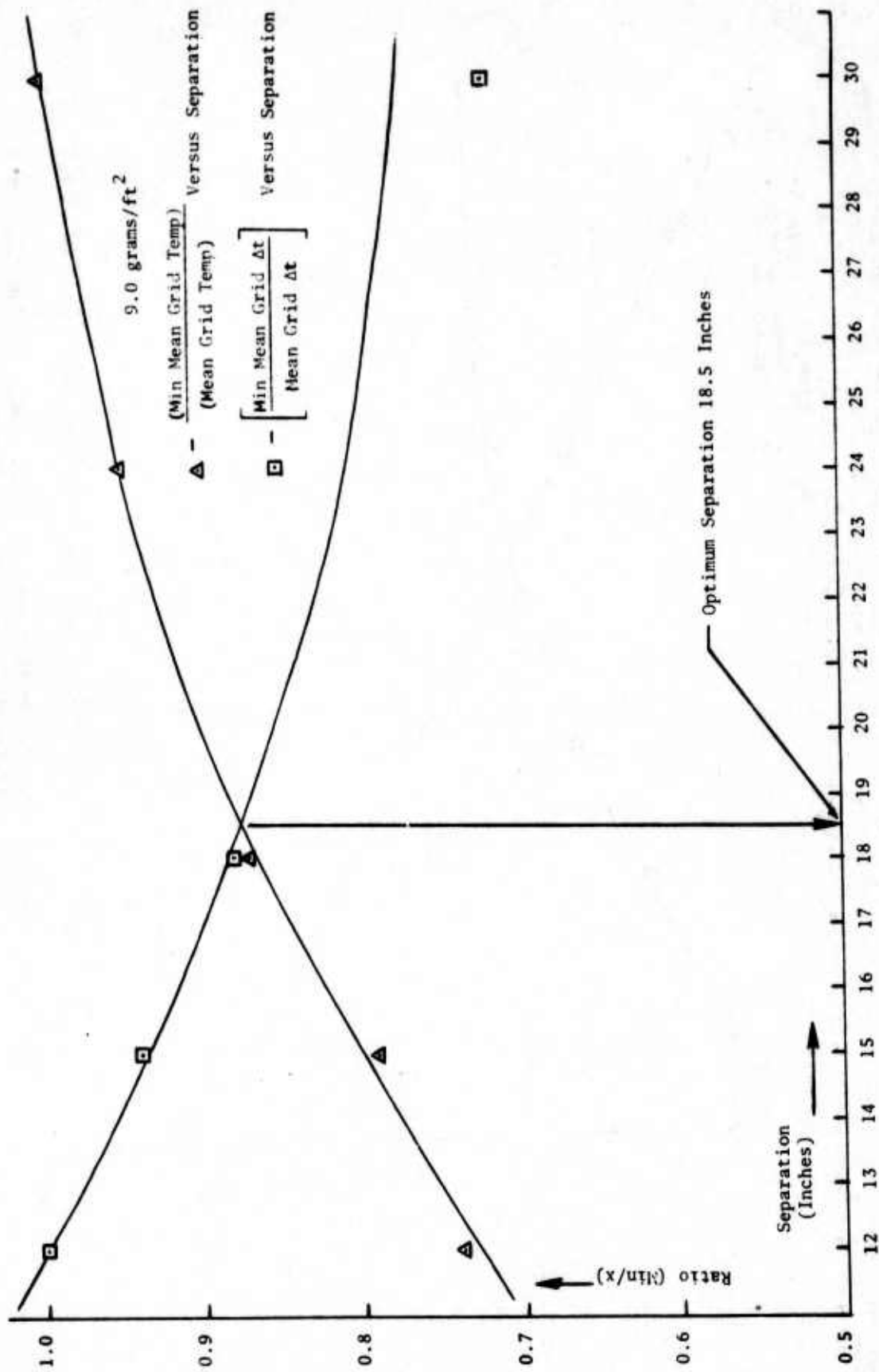


Figure 13. 9 Grams/Ft² With Mean Effective Grid Temperature and Mean Time the Grid Temperature was Above 150°C as the Competing Influences

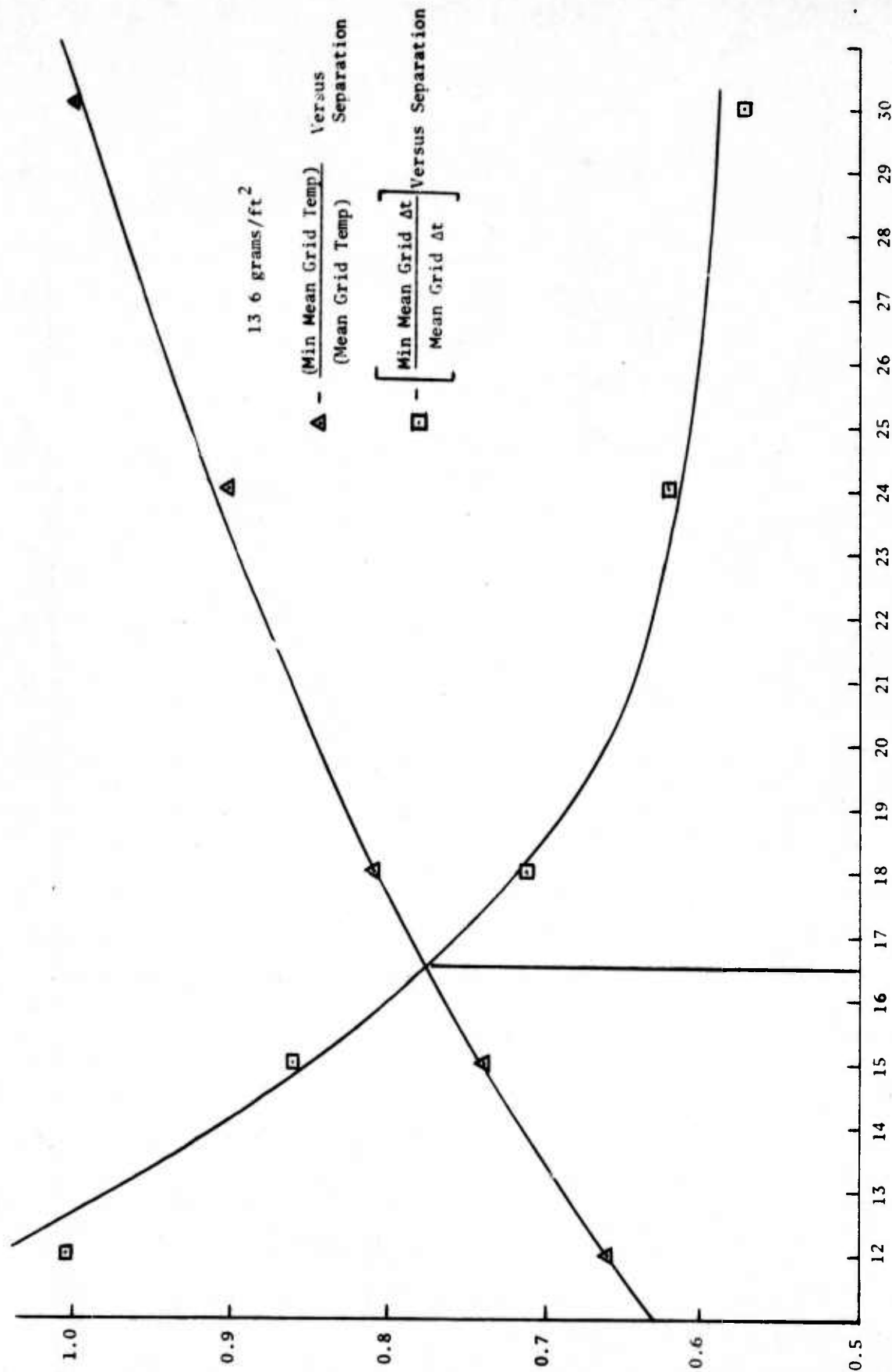


Figure 14. 13.6 Grams/Ft² With Mean Effective Grid Temperature and Mean Time the Grid Temperature was Above 150°C as the Competing Influences

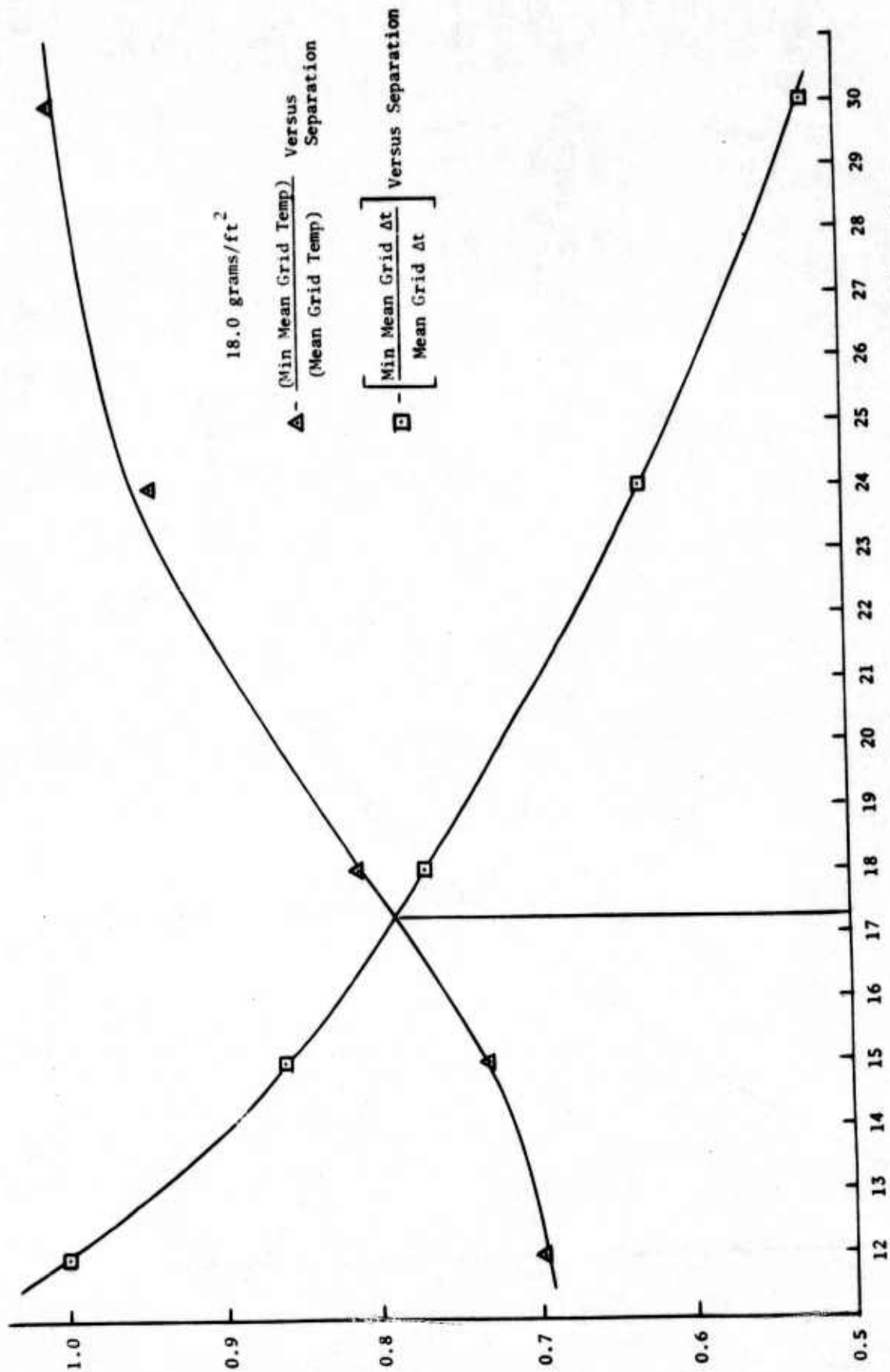


Figure 15. 18.0 Grams/Ft² With Mean Effective Grid Temperature and Mean Time the Grid Temperature was Above 150°C as the Competing Influences

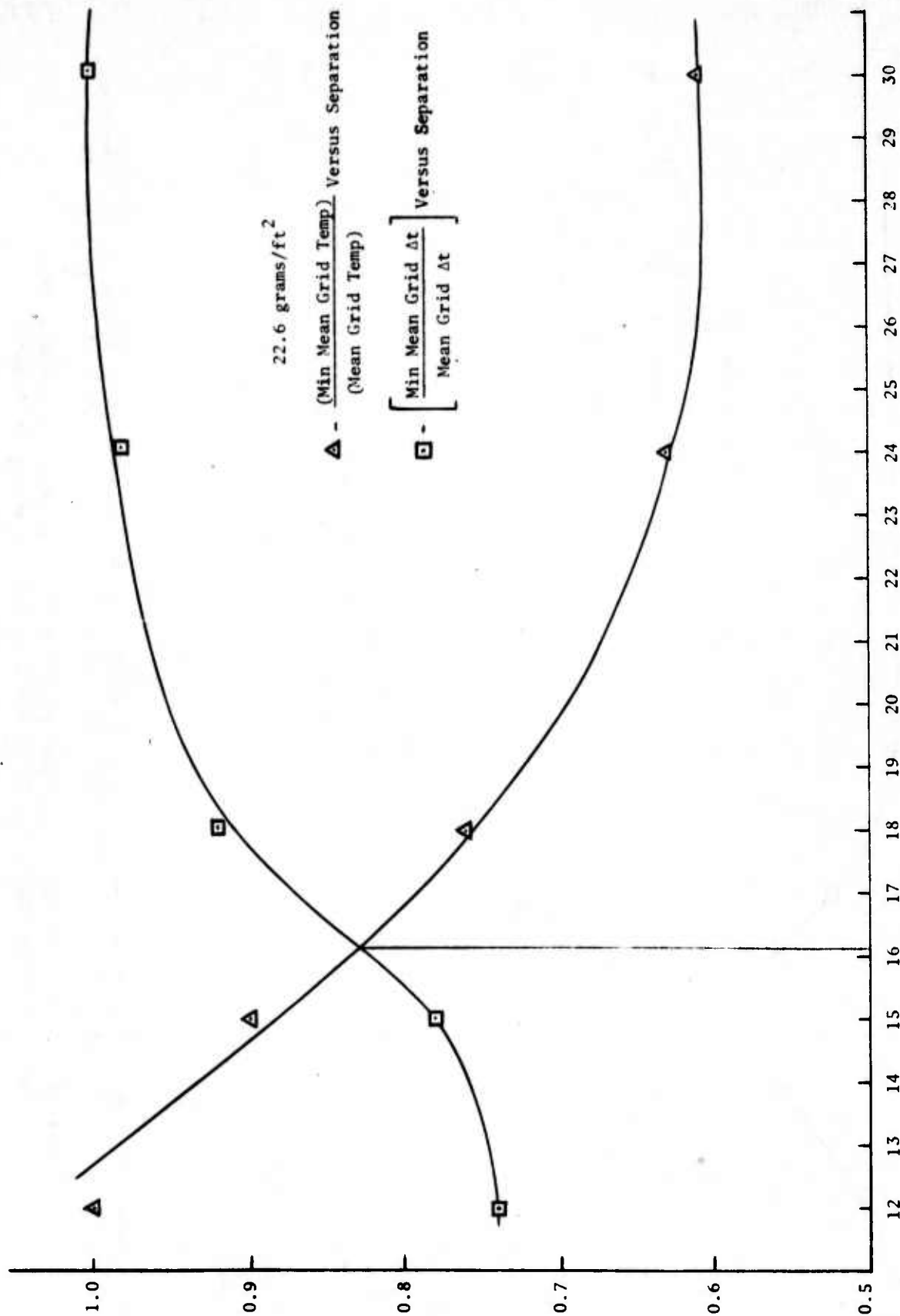


Figure 16. 22.6 Grams/Ft² With Mean Effective Grid Temperature and Mean Time the Grid Temperature was Above 150°C as the Competing Influences

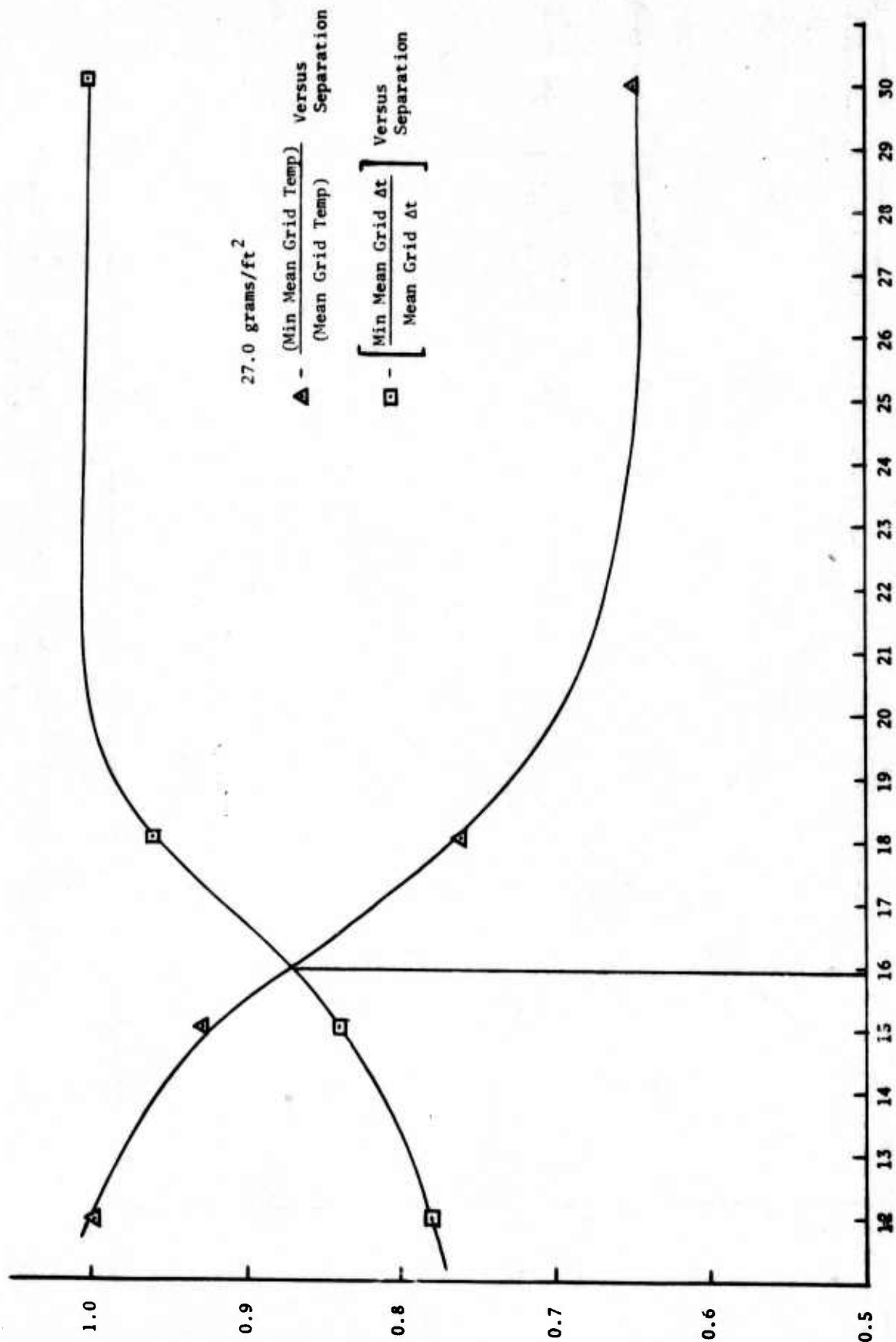


Figure 17. 27.0 Grams/Ft² With Mean Effective Grid Temperature and Mean Time the Grid Temperature was Above 150°C as the Competing Influences

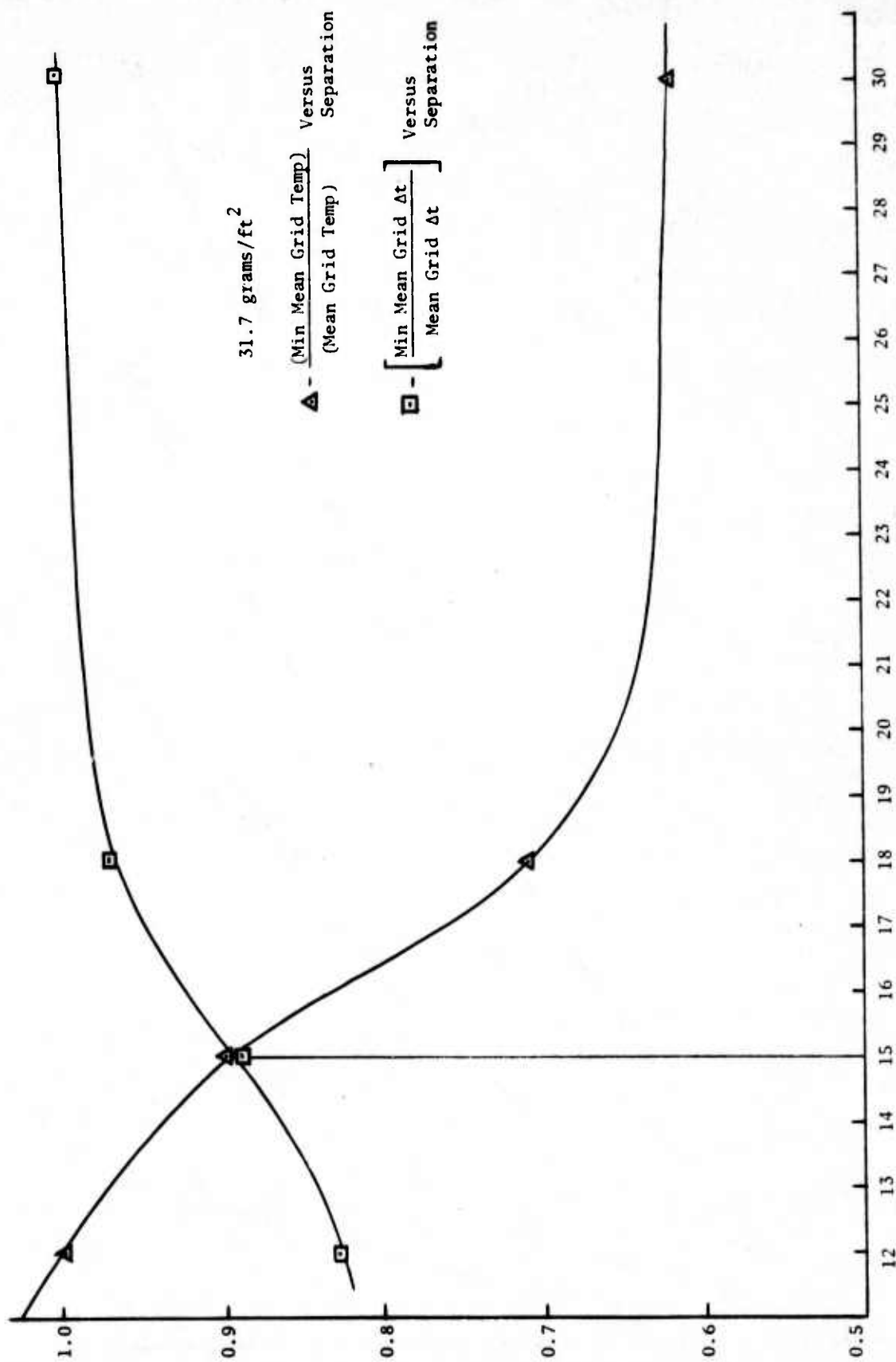


Figure 18. 31.7 Grams/Ft² With Mean Effective Grid Temperature and Mean Time the Grid Temperature was Above 150°C as the Competing Influences

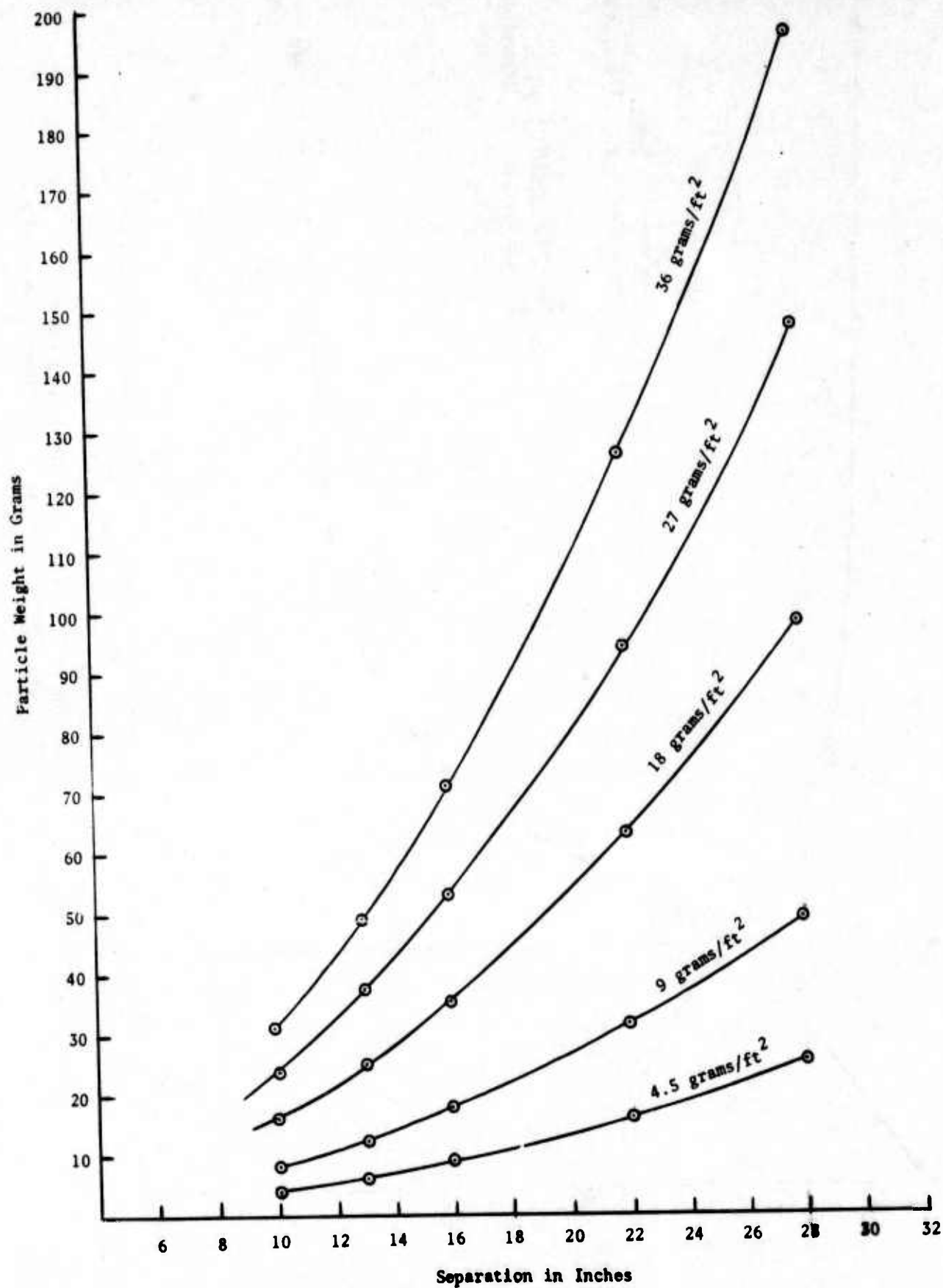


Figure 19. Particle Weight in Grams Versus Separation in Inches for all Densities

SECTION V

EXPERIMENTAL STUDY OF THE OPTIMIZED DISSEMINATION

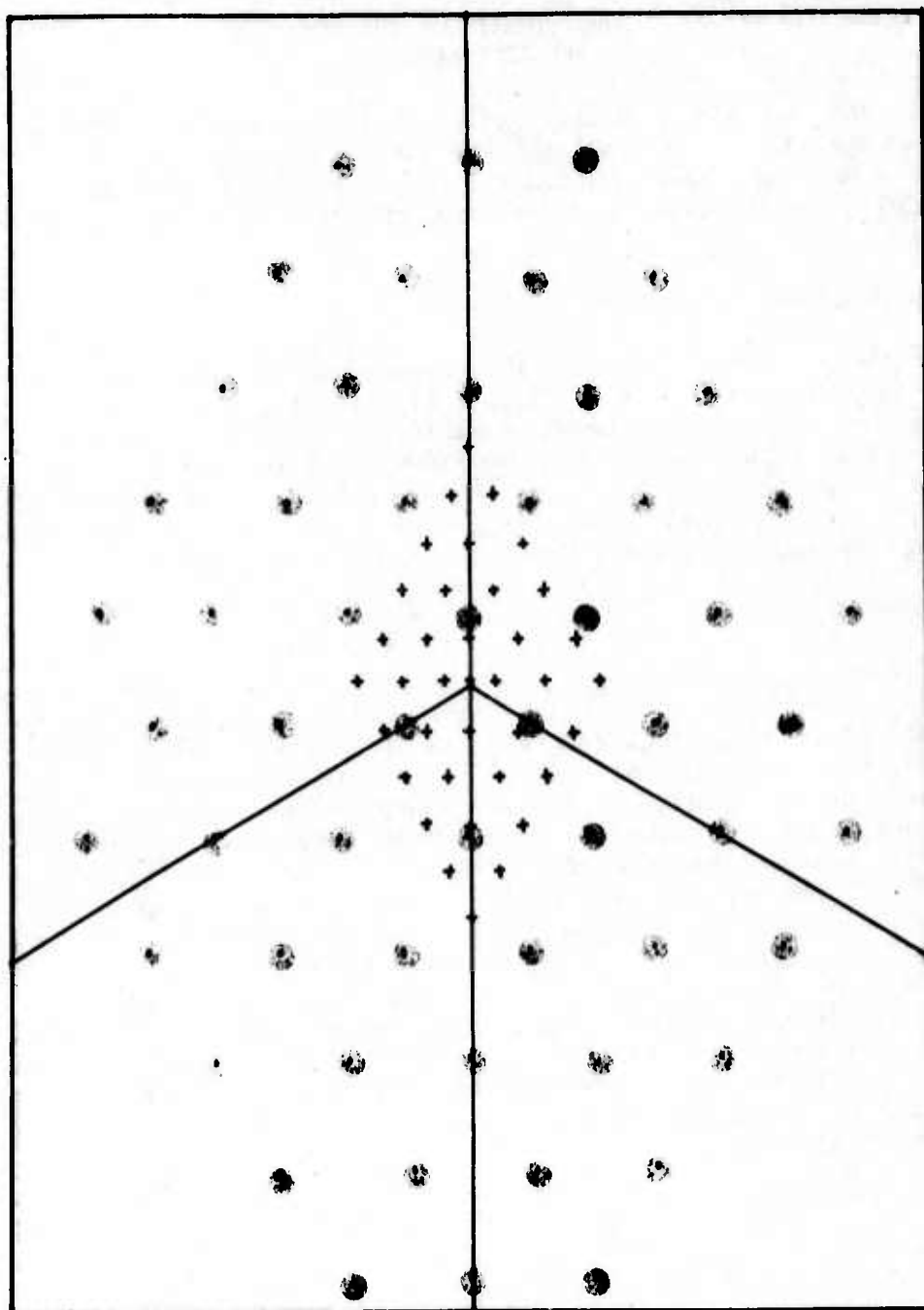
The theoretically predicted optimum dissemination was experimentally studied at the same conditions the data had been collected. This study served as a check on the model and the accuracy of the prediction. This section describes the study and discusses the overall results of this program.

ARRAY CONFIGURATION

Once the parameters defining the proposed optimum fire distribution had been determined an array of fires exhibiting these characteristics had to be constructed. The sample separation distance of 16.5 inches defined the size of the hexagon and the number of fires was based on the placement of the array on the thermocouple grid. The configuration of the hexagons was constructed according to Section II. The array representing the optimum fire distribution is given by Figure 20.

EXPERIMENTAL RESULTS

The theoretical optimum was experimentally checked at ambient and two lower temperatures. The ambient results were compared to the predicted ambient effectiveness from the model. Table 11 gives the averaged results of three experimental runs at each temperature and the theoretical ambient values. Figure 21 compares the results of the three temperatures. The predicted values were almost the same as the actual results of the experiments. The mean effective temperature predicted by the model was 300°C, and the average of three experimental runs was 299°C. The mean time above the minimum effective temperature predicted was 200 seconds, and the actual value obtained from the three runs was 194 seconds. The closeness of these values indicated that the model was well represented by the data collected. While these results are unique to the physical conditions of these experiments and cannot be applied directly to dynamic situations, the technique and results give excellent relative data for the screening of possible dissemination patterns and firebomb effectiveness studies.



+ Thermocouples

Scale 1" = 2'

● Fires

Figure 20. Optimum Fire Array Geometry

Optimum Fire Array
Mean Grid Temperature

Versus
Burn Time
○ Ambient
□ 0°C
▲ -30°C

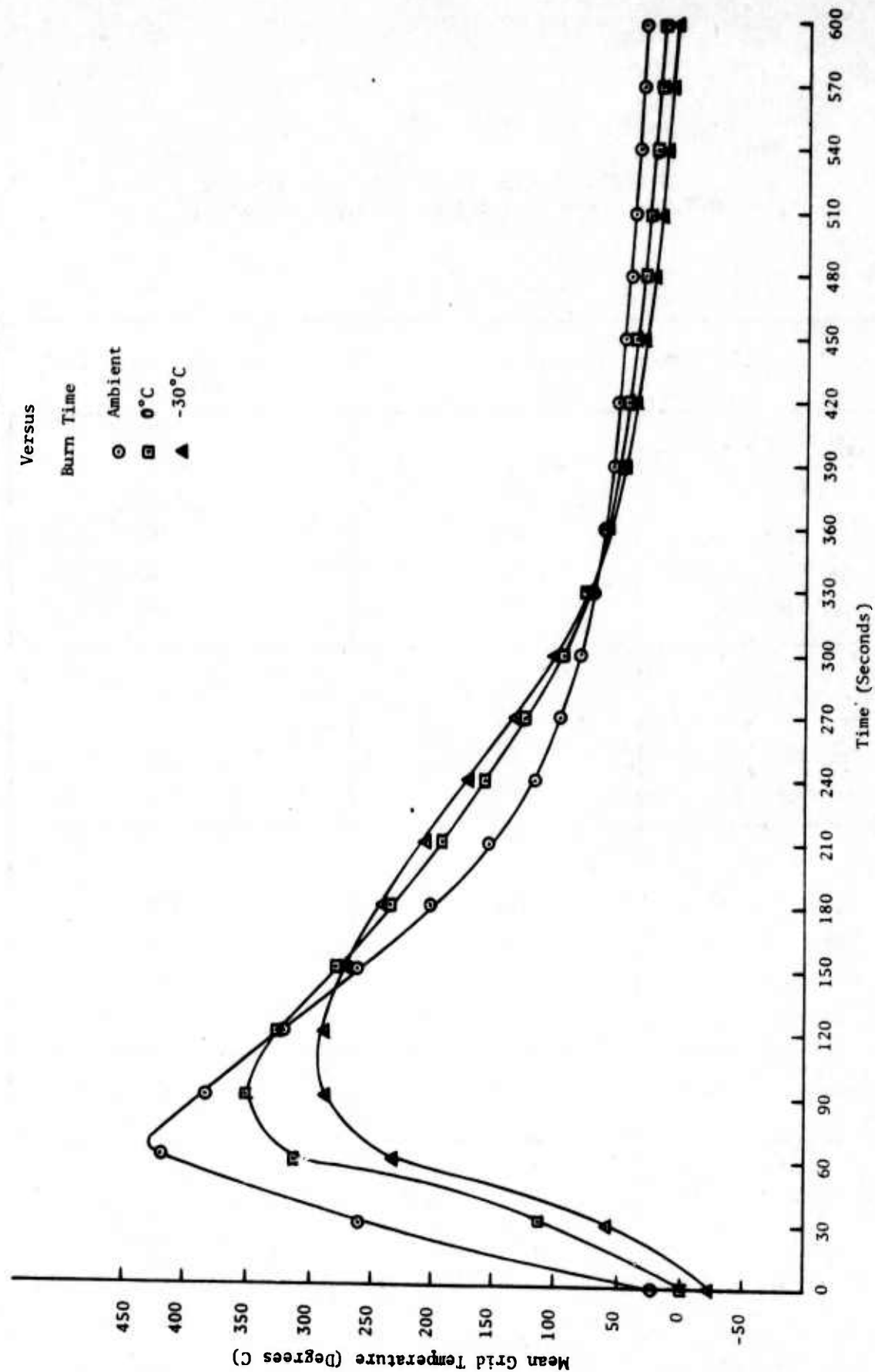


Figure 21. Optimum Fire Array Experimental Results

TABLE 11. EXPERIMENTAL RESULTS OF THE
OPTIMUM ARRAY AT THREE DIFFERENT TEMPERATURES

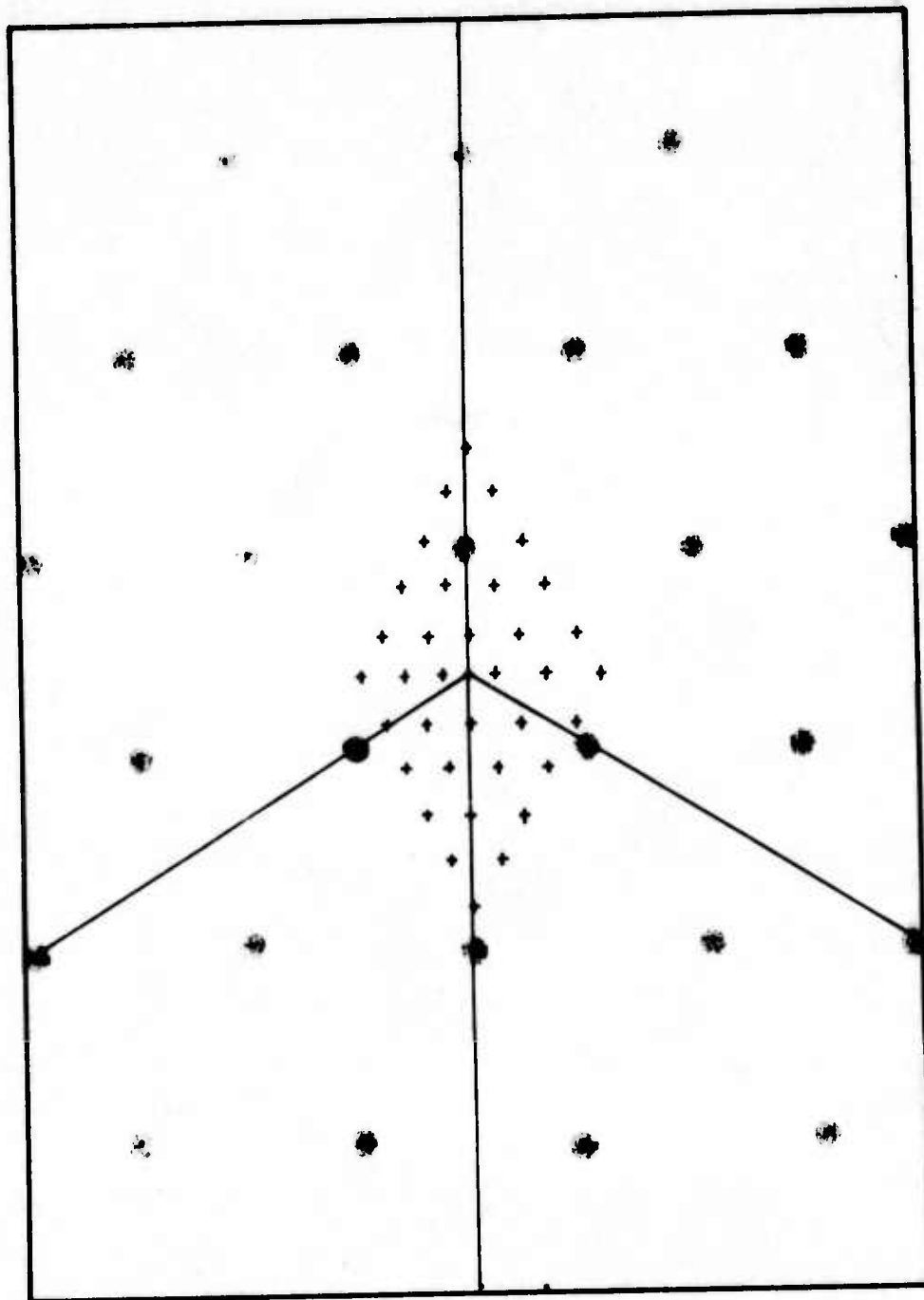
	Mean Temperature Above 150°C (Degrees C)	Mean Time Above 150°C (Seconds)
Ambient		
Run #1	309	186
Run #2	298	210
Run #3	291	186
Average	299	194
0°C		
Run #1	261	210
Run #2	274	210
Average	268	210
-30°C		
Run #1	231	210
Run #2	251	215
Run #3	247	210
Average	243	212
Predicted Ambient	300	200

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2. Long, R. L., Improved Flame Agents, Air Force Armament Laboratory Technical Report AFATL-TR-72-177, Monsanto Research Corporation, September 1972.
3. Rigdon, V. B. Jr., Interim Report on Dynamic Test of Dissemination/Ignition Devices and Flame Agents for Firebombs, Armament Development and Test Center Technical Report ADTC-TR-73-107, December 1973.
4. Nickel, J. A., and Palmer, J. D., Criteria for Casualty Production and Preliminary Flame Pattern Analysis, TM-1454-1-1, University of Oklahoma Research Institute, September 1964.
5. Beveridge, G.S.G., and Schechter, R. S., Optimization: Theory and Practice, McGraw-Hill, 1970.

APPENDIX A

FIRE ARRAYS

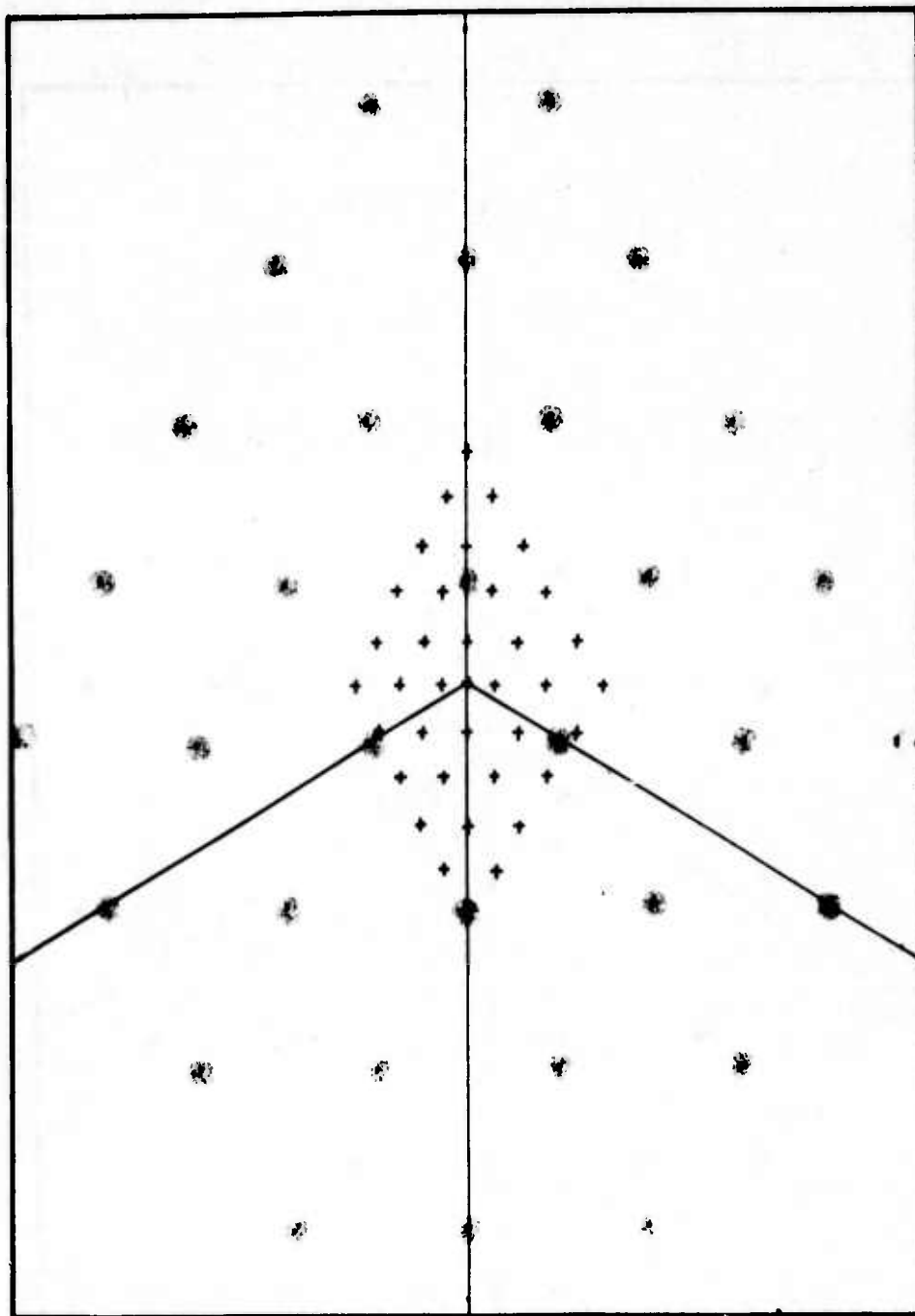


+ Thermocouples

Scale 1" = 2'

• Fires

Separation Distance 2.5 Feet With 25 Fires

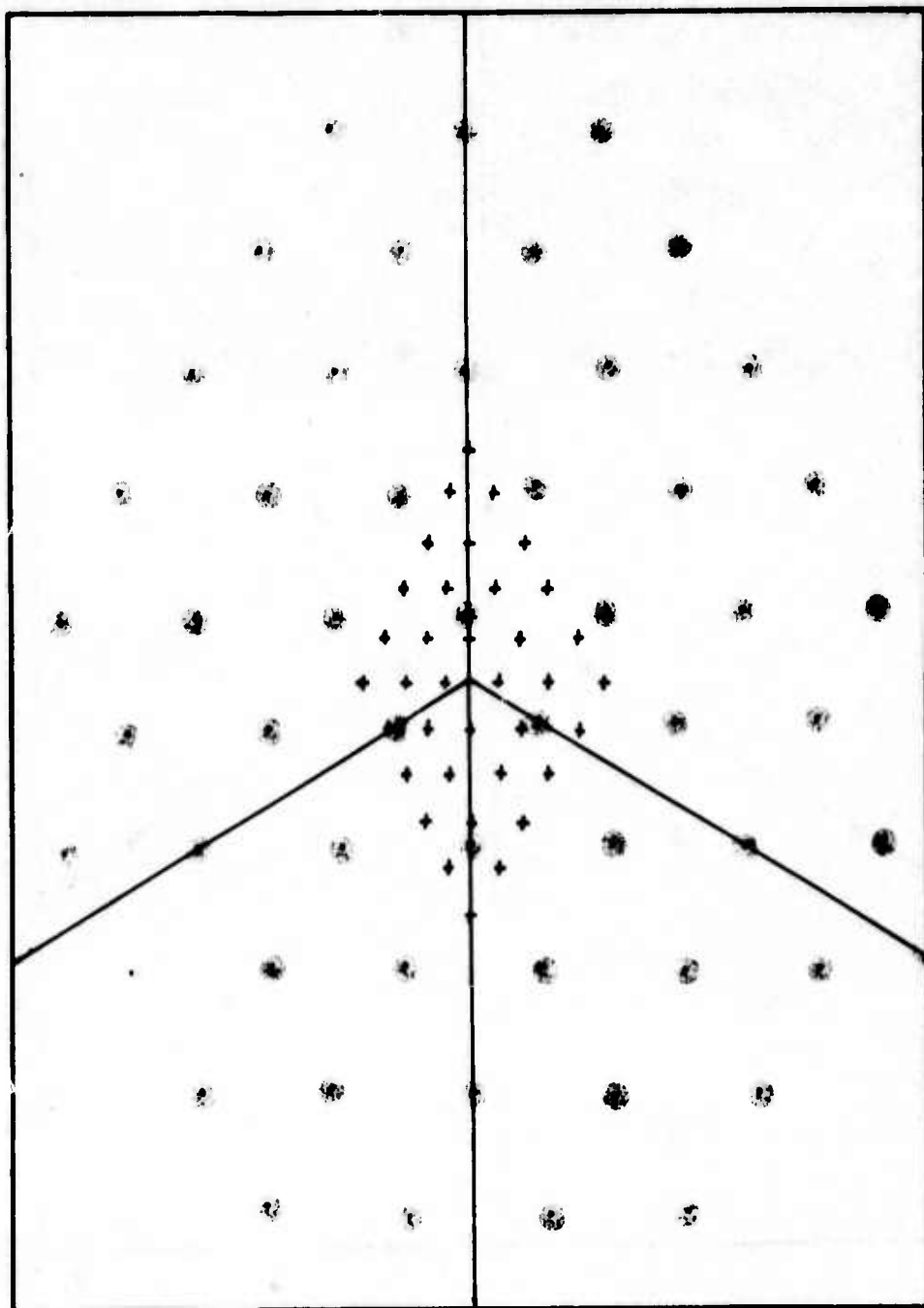


+ Thermocouples

● Fires

Scale 1" = 2'

Separation Distance 2.0 Feet With 32 Fires

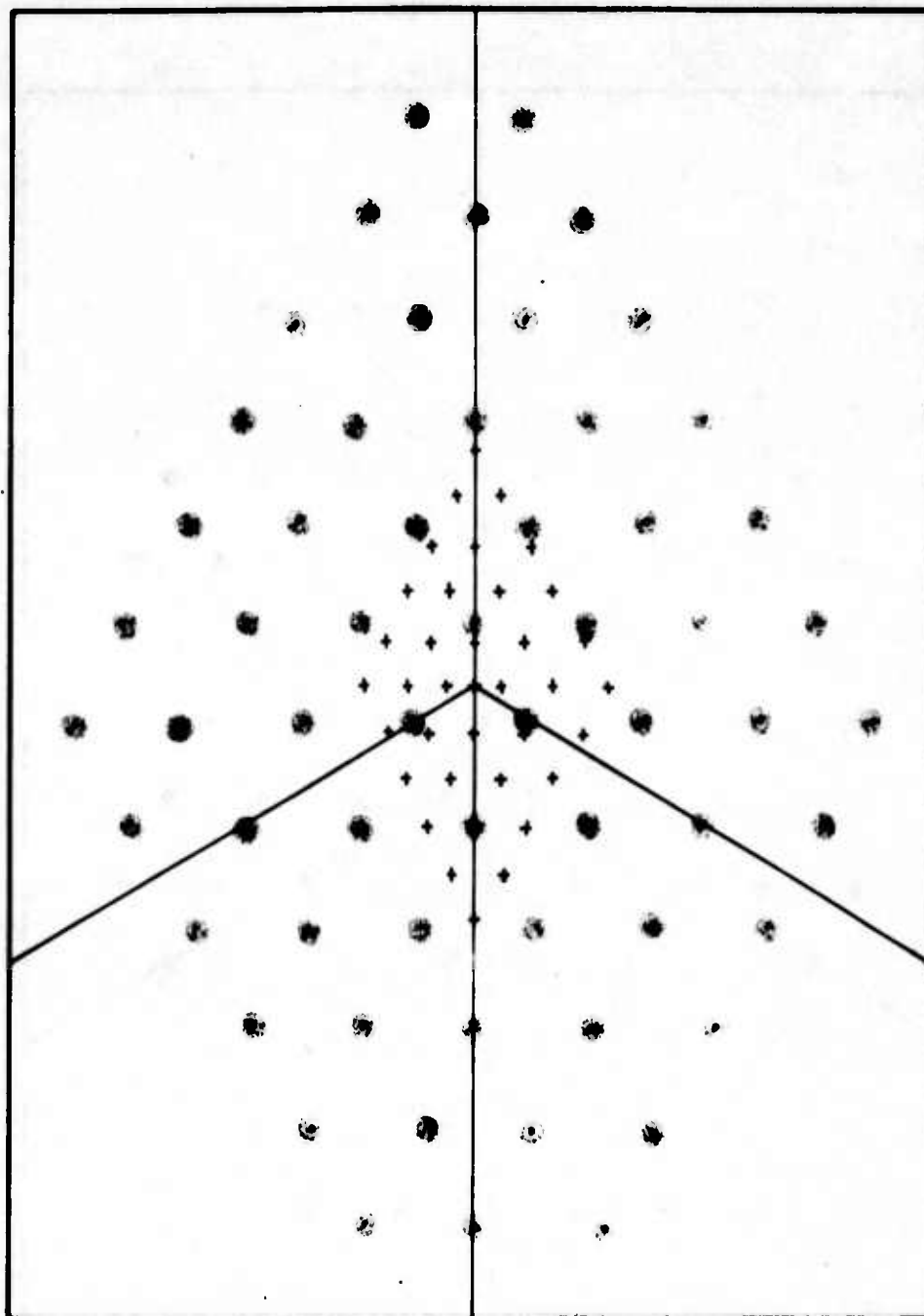


+ Thermocouples

• Fires

Scale 1" = 2'

Separation Distance 1.5 Feet With 53 Fires

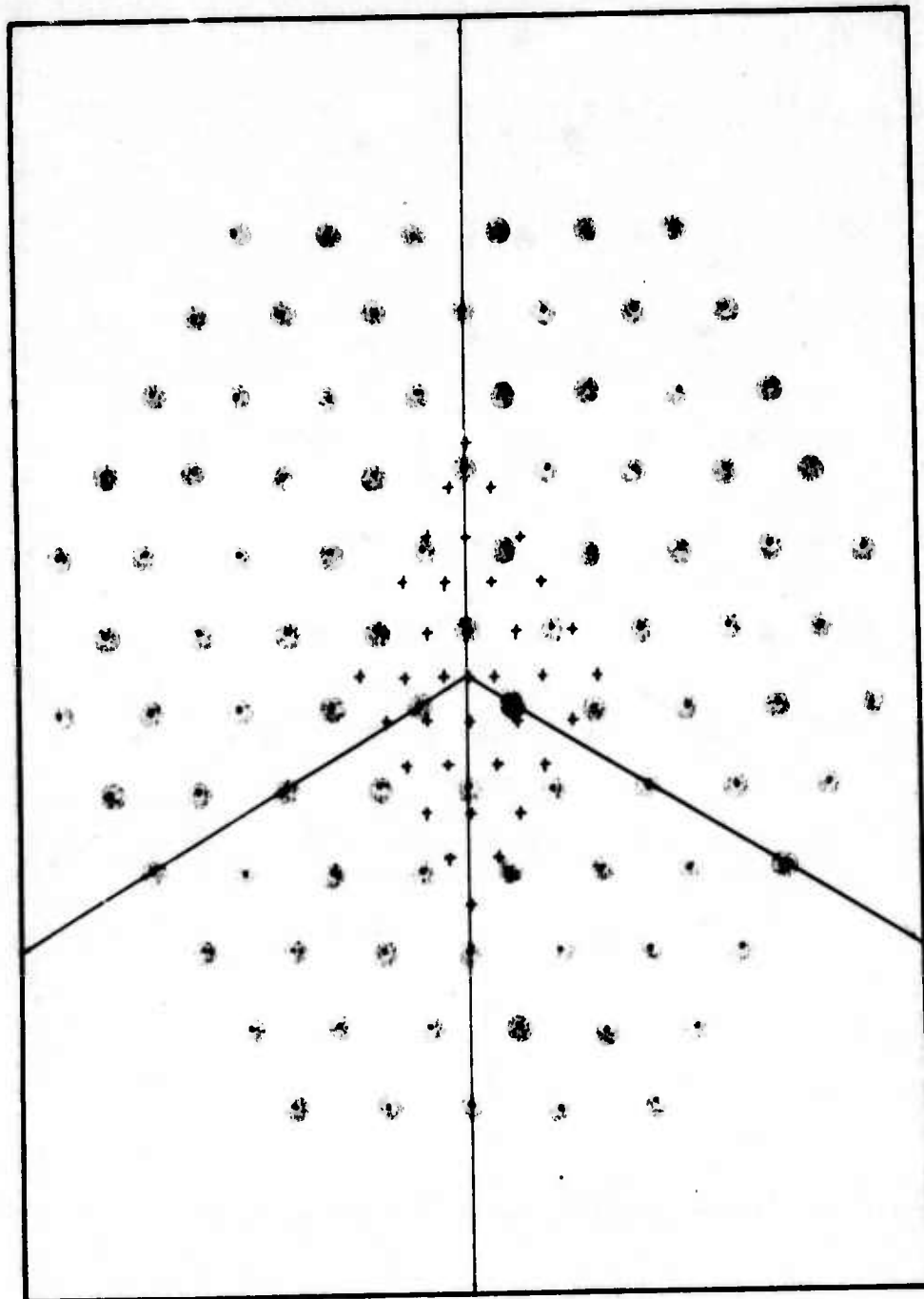


+ Thermocouples

● Fires

Scale 1" = 2'

Separation Distance 125 Feet With 63 Fires



+ Thermocouples

Scale 1" = 2'

● Fires

Separation Distance 1.0 Feet With 96 Fires

APPENDIX B

COMPUTER PROGRAM FOR REDUCTION OF DATA

```

PROGRAM PSDS(INPUT=129,OUTPUT=129,TAPE1,TAPE2,TAPE5=INPUT,TAPE6=0U
1TPUT)
COMMON RAW(240),IARRAY(2+,50),ARRAY(120,48),NARK(80),GRAPH(852)
DIMENSION JARRAY(20,50),MTAB(2401),NSCALE(5),TIME(120),NNBG(6)
EQUIVALENCE(IARRAY(1,1),JARRAY(1,1))
DATA MTAB/1200*(-2,10),0/,NSCALE/1,4*0/

C NUTAP3 IS A CODE INDICATING WHETHER A NEW TAPE IS TO BE USED FOR WRITING OUT
C DATA TO BE SAVED. IF A NEW TAPE IS USED A NUMBER MUST BE PUNCHED IN THE FIRST
C TWO COLUMNS OF THE FIRST CARD. IF AN OLD TAPE IS USED, THE FIRST CARD SHOULD
C BE BLANK OR HAVE A ZERO IN THE SECOND COLUMN. THIS WILL INITIATE A SEARCH FOR
C A DOUBLE END OF FILE INDICATING THE END OF PREVIOUS DATA. ONCE FOUND IT BACK-
C SPACES TO REMOVE ONE EOF AND IS READY TO WRITE.
C
READ(5,9000) NUTAP3
9000 FORMAT(I2)
IF(NUTAP3.NE.0) GO TO 975
900 ASSIGN 910 TO MEOF
CALL EOF(MEOF)
DO 950 M=1,95
READ(3,9010)DUMMY
9010 FORMAT(A10)
GO TO 950
910 ASSIGN 920 TO MEOF
READ(3,9010) DUMMY
GO TO 900
920 BACKSPACE 3
GO TO 975
950 CONTINUE

C THE SECOND CARD READ CONTAINS THE TEMPERATURE COEFFICIENT, TCOEF, FOR
C CONVERSION OF MILLIVOLTS TO DEGREES C AND THE LENGTH OF THE NARRATIVE, NARR.
C ANY THERMOCOUPLE WIRE AND ITS COEFFICIENT MAY BE USED, BUT ALL 44 CHANNELS
C MUST USE THE SAME WIRE. LENGTH IS THE NUMBER OF CARDS USED FOR NARR TIMES
C EIGHT. UP TO TEN CARDS MAY BE USED.
C

```

```

975 READ(5,9020) TCOEF,LENGTH
9820 FORMAT(F4.2,I3)
    READ(5,9025) (NARR(I),I=1,LENGTH)
9025 FORMAT(8A10)
C
C WRITE THE NARRATIVE ON BOTH THE PRINTER AND TAPE3 FOR FUTURE REFERENCE.
C
9029 FORMAT(I3)
    WRITE(6,9999)
9999 FORMAT(1H1,A10)
    WRITE(6,9030) (NARR(I),I=1,LENGTH)
9030 FORMAT(1X,8A10)
9035 FORMAT(13A10)
C
C CALL THE TAPERR FUNCTION TO WATCH FOR PARITY ERRORS AND ASSIGN CONTROL TO
C STATEMENT NUMBER 1110.
C
    ASSIGN 1110 TO ITAPE
    CALL TAPERR(ITAPE)
    ASSIGN 1390 TO MEOF
    CALL EOF(MEOF)
C
C INITIALIZE THE NUMBER OF CHANNELS, NUM, TO BE READ FROM TAPE AS 24, AND THE
C NUMBER OF WORDS, NNUM, TO BE READ AS 240. NOW READY TO READ PYRO LAB TAPE.
C
    NUM=24
    NNUM=240
C
C READ DATA FROM TWO TAPES.
C
    DO 1400 L=1,2
C
C READ 120 RECORDS FROM EACH TAPE. EACH RECORD CONTAINS A FIVE SECOND INTERVAL.
C
    DO 1300 ITIME=1,120
        ICT=0

```

```

C REESTABLISH THE COUNT AS 24 CHANNELS ALREADY READ WHEN READING TAPE2.
C
C IF(L.NE.1) ICT=24
C
C READ THE TAPE USING THE CORRECT NUMBER, NNUM, OF WORDS IN RAW AND UNPACK TAPE.
C
C READ(L) (RAW(K),K=1,NNUM)
C CALL UNPACK(RAW,MTAB,IARRAY(1,1))
C
C AVERAGE EACH CHANNEL OVER THE ENTIRE RECORD(5 SECONDS) AND CONVERT TO DEGREES
C C. THIS VALUE IS TREATED AS THE TEMPERATURE AT THE BEGINNING OF THE INTERVAL.
C
C DO 1100 IP=1,NUM
C   ICT=ICT+1
C   HOLD=0.0
C   DO 1000 J=1,50
C     IF(L.NE.1) GO TO 990
C     HOLD=HOLD+(FLOAT(IARRAY(IM,J)))/10.24
C     GO TO 1000
C   990 HOLD=HOLD+(FLOAT(JARRAY(IM,J)))/10.24
C   1000 CONTINUE
C   ARRAY(ITIME,ICT)=(HOLD/50.0)*TCOEF
C   IF(ICT.GT.40) APRAY(ITIME,ICT)=ARRAY(ITIME,ICT)/2.0
C   1100 CONTINUE
C   GO TO 1300
C
C IF A PARITY ERROR IS ENCOUNTERED THE VALUE OF EACH CHANNEL IS SET EQUAL TO ITS
C VALUE IN THE PRECEDING TIME INTERVAL. IF THE ERROR OCCURS IN THE FIRST
C RECORD, THAT RECORD IS GIVEN THE VALUE 0.0.
C
C 1110 WRITE(6,9040)
C 9040 FORMAT(1X)
C   ASSIGN 1115 TO ITAPE
C   KOUNT=0
C 1115 DO 1200 IN=1,NUM

```

```

ICT=ICT+1
IF(IITIME.NE.1) GO TO 1120
ARRAY(IITIME,ICT)=0.0
GO TO 1200
1120 II=IITIME-1
      ARRAY(IITIME,ICT)=ARRAY(II,ICT)
1200 CONTINUE
C
C THE NUMBER OF PARITY ERRORS ARE COUNTED, AND THE TIME INTERVAL IN WHICH AN
C ERROR OCCURS IS PRINTED OUT.
C
      KOUNT=KOUNT+1
      WRITE(6,9045) IITIME
9045 FORMAT(1X,19HPARITY ERROR IN THE,I4,16HTH TIME INTERVAL)
1300 CONTINUE
C
C NUM, NNUM, AND MTAB(2001) ARE REINITIALIZED TO READ THE SECOND TAPE CONTAINING
C ONLY TWENTY CHANNELS.
C
      NUM=20
      NNUM=200
      MTAB(2001)=0
1390 WRITE(6,9199) L,IITIME
9199 FORMAT(1H0,17HEOF FOUND ON TAPE,I3,10HRECORD NO.,I4)
1400 CONTINUE
      READ(5,9200) NRG,NBF,NBR
9200 FORMAT(3I2)
      IF(NRG.EQ.0) GO TO 1405
      READ(5,9210) (NNRG(I),I=1,NRG)
9210 FORMAT(40I2)
      DO 1404 KLUX=1,NRG
      KLAN=NNRG(KLUX)
      DO 1403 KLU=1,120
      ARRAY(KLU,KLAN)=0.0
1403 CONTINUE
1404 CONTINUE
1405 FNTC=37.0-FLOAT(NRG)

```

```

IF (NBF.EQ.0) GO TO 1410
READ(5,9210) (NNBG(I),I=1,NBF)
DO 1409 KLAX=1,NBF
  KLIX=NNBG(KLAX)
  DO 1408 KLOX=1,120
    ARRAY(KLOX,KLIX)=0.0
1408 CONTINUE
1409 CONTINUE
1410 FNTCF=3.0-NBF
  IF (NBR.EQ.0) GO TO 1420
  READ(5,9210) (NNBG(I),I=1,NBR)
  DO 1415 KLANG=1,NBR
    KLONG=NNBG(KLANG)
    DO 1414 KLING=1,120
      ARRAY(KLING,KLONG)=0.0
1414 CONTINUE
1415 CONTINUE
1420 FNTCR=4.0-NBR
  IF (FNTCR.EQ.0.0) FNTCR=1.0
C
C AVERAGE ARE CALCULATED FOR EACH OF 120 TIME INTERVALS AND STORED IN AN ARRAY
C 120 BY 48 CHANNELS.
C
  DO 1500 JJ=1,120
C
C CALCULATE THE AVERAGE OF ALL 37 THERMOCOUPLES IN THE GRID
C
  RETAIN=0.0
  DO 1425 KK=1,37
    RETAIN=RETAIN+ARRAY(JJ,KK)
1425 CONTINUE
  ARRAY(JJ,45)=RETAIN/FNTC
C
C CALCULATE THE AVERAGE THREE THERMOCOUPLES IN FIRES AND THEIR AVERAGE WITH THE
C 37 PRECEDING THERMOCOUPLES.
C
  RETAIN=0.0
  DO 1450 KK=38,40
    RETAIN=RETAIN+ARRAY(JJ,KK)

```

```

1450 CONTINUE
  ARRAY(JJ,46)=(FNTC*ARRAY(JJ,45)+RETAIN)/(FNTC+FNTCF)
  IF(FNTCF.EQ.0.0) FNTCF=1.0
  ARRAY(JJ,47)=RETAIN/FNTCF

C
C CALCULATE THE AVERAGE OF FOUR SETS OF THERMOCOUPLES MONITORING ROOM TEMP.
C
  RETAIN=0.0
  DO 1475 KK=41,44
    RETAIN=RETAIN+ARRAY(JJ,KK)
1475 CONTINUE
  ARRAY(JJ,48)=RETAIN/FNTCF
1500 CONTINUE

C
C WRITE OUT THE ENTIRE ARRAY FOR REFERENCE WITH THE PRINTED DATA.
C ON TAPE3 WRITE THE ENTIRE ARRAY, 17 VALUES PER RECORD, FOLLOWED BY THE NUMBER
C OF PARITY ERRORS. WRITE END OF FILE MARK TO INDICATE END OF DATA TO BE SAVED.
C
  WRITE(6,9999) NARR(1)
  WRITE(6,9046)
9046 FORMAT(1H,133HCHANNEL      1      2      3      4      5      12      13      14
           1 6      7      8      9      10     11     12     13     14
           2      15     16)
  WRITE(6,9044)
9044 FORMAT(1H0,3X,3HSEC)
  ISNT=0
  DO 1505 IS=1,60
    ISNT=ISNT+5
    WRITE(6,9047) ISNT,(APRAY(IS,NOT),NOT=1,16)
9047 FORMAT(3X,I3,3X,16F8.1)
1505 CONTINUE
  WRITE(6,9999) NARR(1)
  WRITE(6,9046)
  WRITE(6,9044)
  DO 1510 IS=61,120
    ISNT=ISNT+5
  WRITE(6,9047) ISNT,(ARRAY(IS,NOT),NOT=1,16)

```

```

1510 CONTINUE
WRITE(6,9999) NARR(1)
WRITE(6,9048)
9048 FORMAT(1H,133HCHANNEL      17      18      19      20      21      29      30
122      23      24      25      26      27
2      31      32)
WRITE(6,9044)
11(11);
DO 1515 IS=1,60
ISNT=ISNT+5
WRITE(6,9047) ISNT,(ARRAY(IS,NOT),NOT=17,32)

1515 CONTINUE
WRITE(6,9999) NARR(1)
WRITE(6,9048)
WRITE(6,9044)
DO 1520 IS=61,120
ISNT=ISNT+5
WRITE(6,9047) ISNT,(ARRAY(IS,NOT),NOT=17,32)

1520 CONTINUE
WRITE(6,9999) NARR(1)
WRITE(6,9049)
9049 FORMAT(1H,133HCHANNEL      33      34      35      36      37      45      46
130      39      40      41      42      43      44
2      47      48)
WRITE(6,9044)
ISNT=0
DO 1525 IS=1,60
ISNT=ISNT+5
WRITE(6,9047) ISNT,(ARRAY(IS,NOT),NOT=33,48)

1525 CONTINUE
WRITE(6,9999) NARR(1)
WRITE(6,9049)
WRITE(6,9044)
DO 1530 IS=61,120
ISNT=ISNT+5
WRITE(6,9047) ISNT,(ARRAY(IS,NOT),NOT=33,48)

1530 CONTINUE
9050 FORMAT(17F8.1)
9051 FORMAT(I3)

```

```

C READ THE LIMITING TEMPERATURE FOR CALCULATING THE INTERVAL OF MAXIMUM HEAT
C OUTPUT.
C

```

```

      READ(5,9055) TMIN
      FORMAT(F4.0)
9055  WRITE(6,9999) NARR(1)
      WRITE(6,9060)
9060  FORMAT(1H ,8X,17HTOTAL HEAT OUTPUT,7X,29HMAXIMUM
      1PUT,10X,7HMAXIMUM,5X,7HTIME AT)
      WRITE(6,9061)
9061  FORMAT(11X,81HAREA AVE TEMP AREA AVE TEMP START END DELTA
      1 TIME TEMPERATURE MAX TEMP)
      WRITE(6,9062)
9062  FORMAT(1X,90HCHANNEL DEG-SEC DEG C DEG-SEC DEG C SEC
      1SEC SECONDS)

```

```

C INITIALIZE VALUES FOR DETERMINING THE AVERAGES FOR THERMOCOUPLES ABOVE THE
C LIMITING TEMPERATURES.
C

```

```

      SUM3=0.0
      COUNT=0.0
      TSYM=0.0
      TTYM=0.0
      TTYM=0.0

```

```

C INTEGRATE UNDER CURVE FOR ALL 48 CHANNELS. DETERMINE MAXIMUM TEMPERATURE, ETC
C BOTH INTEGRATIONS ARE CARRIED OUT SIMULTANEOUSLY.
C

```

```

      DO 1700 NN=1,48

```

```

C INITIALIZE VALUES USED IN INTEGRATIONS.
C

```

```

      ICOUNT=0
      SUM1=0.0
      SUM2=0.0
      TMAX=ARRAY(120,NN)
      TYMX=600.0
      NTIME=1

```

```

C C INTEGRATION IS CARRIED OUT ASSUMING THE FIRST AND LAST TEMPERATURES ARE BELOW
C C TMIN, THE LIMITING TEMPERATURE.
C
C DO 1600 MM=1,120
C
C C SUM TOTAL AREA UNDER THE CURVE, THEN SEARCH FOR THE MAXIMUM TEMPERATURE AND
C C WHEN IT APPEARS.
C C
C SUM1=ARRAY(MM,NN)+SUM1
C IF(ARRAY(MM,NN).LT.TMAX) GO TO 1550
C TMAX=ARRAY(MM,NN)
C TYMX=(FLOAT(MM))*5.0
C
C C SUM AREA UNDER THE CURVE WITH THE TEMPERATURE ABOVE THE LIMITING TEMPERATURE.
C
C 1550 IF(ARRAY(MM,NN).LT.TMIN) GO TO 1600
C ICOUNT=ICOUNT+1
C 1600 SUM2=SUM2+ARRAY(MM,NN)
C NTIME=MM
C 1600 CONTINUE
C
C C CALCULATE ACTUAL AREA UNDER THE ENTIRE CURVE AND THE TIME AVERAGE TEMPERATURE.
C C THEN CALCULATE THE ACTUAL AREA, START TIME, END TIME, TOTAL TIME, AND TIME
C C AVERAGE TEMPERATURE FOR THE INTERVAL OF MAXIMUM OUTPUT.
C
C SUM1=SUM1*5.0
C AVTMP=SUM1/600.0
C SUM2=SUM2*5.0
C TYM=(FLOAT(ICOUNT))*5.0
C STYM=(FLOAT(NTIME-ICOUNT))*5.0
C FTYM=(FLOAT(NTIME))*5.0
C ATMP=SUM2/TYM
C IF(TYM.NE.0.0) GO TO 1605
C FTYM=0.0
C STYM=0.0
C ATMP=0.0
C SUM2=0.0

```

```

1685 CONTINUE
WRITE(6,9070) NN,SUM1,AVTMP,SUM2,ATMP,STYM,FTYM,TYM,TMAX,TYMX
9070 FORMAT(1X,2X,I2,4X,F7.0,4X,F4.0,4X,F7.0,4X,F4.0,5X,F4.0,2X,F4.0,3X
1,F4.0,8X,F4.0,9X,F4.0)

```

```

C THE AVERAGE AREA AND TIME AVERAGE TEMPERATURE FOR ALL THERMOCOUPLES IS
C CALCULATED FOR THE PERIOD DURING WHICH THE THERMOCOUPLE IS ABOVE TMIN. THE
C AVERAGE START, END, AND TOTAL TIME FOR THESE PERIODS IS ALSO CALCULATED.
C

```

```

IF (NN.GT.37) GO TO 1700
SUM3=SUM2+SUM3
TSTYM=TSYM+STYM
TFTYM=FTYM+FTYM
TTYM=TYM+TYM
IF (SUM2.EC.0.0) GO TO 1700
COUNT=COUNT+1.0

```

```

1700 CONTINUE
SUM4=SUM3/FNTC
ATSYM=TSYM/FNTC
ATFTYM=TFTYM/FNTC
ATTYM=TTYM/FNTC
AAATMP=SUM4/ATTYM
SUM3=SUM3/COUNT
TSTYM=TSYM/COUNT
TFTYM=TFTYM/COUNT
TTYM=TTYM/COUNT
AATMP=SUM3/TTYM

```

```

WRITE(6,9074) SUM4,AAATMP,ATSYM,ATFTYM,ATTYM
9074 FORMAT(1H0,15HAVE OF ALL TC'S,13X,F6.0,4X,F4.0,5X,F4.0,2X,F4.0,3X,
1F4.0)

```

```

WRITE(6,9075) SUM3,AATMP,TSYM,TFTYM,TTYM
9075 FORMAT(1H,18HAVE FOR TC'S ABOVE/1X,8HMAX TEMP,20X,F6.0,4X,F4.0,5X
1,F4.0,2X,F4.0,3X,F4.0)

```

```

C READ THREE VALUES, INIT, IFIN, AND INCREM, TO DEFINE THE FIRST INTERVAL TO BE
C PLOTTED, THE LAST TIME INTERVAL TO BE PLOTTED, AND THE INCREMENTS IN WHICH TO
C PRINT THEM. THERE ARE 120 TIME INTERVALS WHICH CAN BE PLOTTED.
C

```

```

      READ(5,9080) INIT,IFIN,INCREM
9080  FORMAT(3I3)
C
C  INITIALIZE TIME ARRAY TO CONTAIN TWELFTH MINUTES CORRESPONDING TO 5 SECONDS.
C
      DO 1800 LN=1,120
      TIME(LN)=(FLOAT(LN))*0.083333
1800  CONTINUE
C
C  PLOT TEMPERATURE-TIME CURVES FOR THE TIME INTERVALS REQUESTED.
C
      DO 1900 LK=INIT,IFIN,INCREM
      WRITE(6,9999) NARR(1)
      CALL PLOT1(INSKALE,10,7,10,11)
      CALL PLOT2(GRAPH,852,0.0,10.0,0.0,1000.0)
      CALL PLOT3(GRAPH,1H*,TIME(1),ARRAY(1,LK),120)
      CALL PLOT4(GRAPH,44,44H
1C)
      WRITE(6,9090)
9090  FORMAT(1H0,62X,12HTIME MINUTES)
      WRITE(6,9100) LK
9100  FORMAT(1H0,50X,35HTEMPERATURE VERSUS TIME FOR CHANNEL,I3)
1900  CONTINUE
C
C  READ LIMITS ON DO LOOP PLOTTING TEMPERATURE MAP OF THERMOCOUPLE GRID.
C
      READ(5,9080) IBEG,IEND,ICHG
C
C  PRINT OUT TEMPERATURE MAP OF THERMOCOUPLE GRID AT SPECIFIED TIME INTERVALS.
C
      DO 2000 II=IBEG,IEND,ICHG
      TYME=(FLOAT(II))*5.0
      WRITE(6,9110) TYME,NARR(1)
9110  FORMAT(1H1,19HTHERMOCOUPLE MAP AT,F4.0,5H SEC.,5X,A10)
      WRITE(6,9120) ARRAY(II,1)
      WRITE(6,9130) (ARRAY(II,IT),IT=2,3)

```

TEMPERATURE DEGREES

```

WRITE(6,9140) (ARRAY(II,IT), IT=4,6)
WRITE(6,9150) (ARRAY(II,IT), IT=7,10)
WRITE(6,9160) (ARRAY(II,IT), IT=11,15)
WRITE(6,9170) (ARRAY(II,IT), IT=16,18), (ARRAY(II,IT), IT
1=19,21)
WRITE(6,9160) (ARRAY(II,IT), IT=22,26)
WRITE(6,9150) (ARRAY(II,IT), IT=27,30)
WRITE(6,9140) (ARRAY(II,IT), IT=31,33)
WRITE(6,9130) (ARRAY(II,IT), IT=34,35)
WRITE(6,9180) ARRAY(II,36)
FORMAT(1H+,65X,F4.0////////)
9120 FORMAT(60X,2(F4.0,8X)////////)
9130 FORMAT(54X,F4.0,7X,F4.0,9X,F4.0////////)
9140 FORMAT(49X,F4.0,7X,F4.0,8X,F4.0,9X,F4.0////////)
9150 FORMAT(43X,2(F4.0,7X),3(F4.0,9X)////////)
9160 FORMAT(38X,2(F4.0,7X),2(F4.0,2X),3(F4.0,9X)////////)
9170 FORMAT(55X,F4.0)
9180 CONTINUE
2000 STOP
END
SUBROUTINE PLOT1 (N1,N2,N3,N4,N5)

```

```

PLOT1 SETS UP THE GRID SPACING AND THE TOTAL WIDTH AND LENGTH OF
THE GRAPH IMAGE. IT ALSO DETERMINES THE LOCATION OF THE DECIMAL
POINTS AND THE MULTIPLYING FACTORS (POWERS OF 10 FOR VALUES OF THE
ORDINATE AND ABSCISSA TO BE PRINTED AT THE GRID LINES)

```

```

REAL LINPLN
INTEGER WORDS,COLS,COLM1
DIMENSION IVT(15), NP2(4), N1(5), SCALE(5)
COMMON /CCMPLOT/ NSCALE(5), NHL, NSBH, NVL, NSBV, XMAX, XMIN, YMAX, YMIN, I
1BCD, NDATA, IOMIT, NOBOT, NOORD, NOAB, VT(15), COLM1, COLS, LINES, WORDS, IDA
2SH(12), ISPACE(12), UNYPLIN, UNXPCOL, LINPUNY, CCLPUNX, MAT1(3), MAT2(2),
3MAT3(3), ISIZE, KORE, LIMIT, BAD1, BAD2, BAD3, I, J, K, MPC, NCHAR, NGT9, LAB
EQUIVALENCE (VT, IVT), (NP2, NHL), (NSCALE, SCALE)
DATA IZ, M1, M2, M3, M4, M5/33B, 7700000000000000B, 7777770000000000B, 1000000
1000000B, 7700000B, 100000000B/

```

NSCALE(5)	PARMS (USED TO ALTER STANDARD PLOTS)
NHL	NO. HORIZONTAL GRID LINE
NSBH	NO. OF SPACES BETWEEN HOR. GRIDS
NVL	NO. OF VERTICAL GRID LINES
NSBV	NO. OF SPACES BETWEEN VERT. GRIDS
XMAX	VALUE OF ABSCISSA AT RIGHT GRID
XMIN	VALUE OF ABSCISSA AT LEFT GRID
YMAX	VALUE OF ORDINATE AT TOP GRID
YMIN	VALUE OF ORDINATE AT BOTTOM GRID
IBCD	B/C D PLOT CHARACTER
NDATA	NO. OF POINTS TO PLOT (SINGLE CALL)
ICMIT	VALUE OF ARG CF OMIT CALL
NOBOT	FLAG FOR OMITTING BOTTOM GRID LINE
NOORD	FLAG FOR OMITTING ORDINATE VALUES
NOAB	FLAG FOR OMITTING ABSCISSA VALUES
VT(15)	TEMPORARY WORKING AREA
COLM1	NO. OF COLUMNS-1 IN A LINE (IMAGE)
COLS	NO. COLUMNS IN A LINE (IMAGE)
LINES	NO. OF LINES TO BE PLOTTED
WORDS	NO. OF WORDS IN A LINE
IDASH(13)	USED FOR GENERATING HOR. GRID LINES
ISPACE(13)	USED FOR GENERATING VERT GRID LINES
UNYPLIN	UNITS OF Y PER LINE
UNXPCOL	UNITS OF X PER COLUMN
LINPUNY	LINES PER UNIT OF Y
COLPUNX	LINES PER UNIT OF X
MAT1(3)	VARIABLE FCRMAT (HOR GRID LINE)
MAT2(2)	VARIABLE FCRMAT (NON-GRID LINE)
MAT3(3)	VARIABLE FCRMAT (ORDINATE VALUES)
ISIZE	SIZE OF IMAGE AREA (WORDS*LINES)
KORE	NO. OF CHARACTERS/MEMORY WORD (6600=10)
LIMIT	MAX NO. CHARACTERS/LINE (501 PRINTER = 123)
BAD1	FLAG (BAD PLOT 1 CALL)
BAD2	FLAG (BAD PLOT 2 CALL)
BAD3	FLAG (BAD PLOT 3 CALL)
I	COMMON VAR

54	J	COMMON VAR	54
55	K	COMMON VAR	55
56	MPC	RIGHTMOST CHARACTER MASK	56
57	NCHAR	NO. CHARACTERS IN LABEL ARRAY	57
58	NGT9	NO. SPACES BETWEEN PRINTER VERT GRIDS	58
59	LAB	TEMPORARY	59
60	IZ	BIAS TO CONVERT TO DISPLAY CODE	60
61			61
62			62
63			63
64			64
65			65
66			66
67			67
68			68
69			69
70			70
72			72
73			73
74			74
75			75
76			76
77			77
78			78
79			79
80			80
81			81
82			82
83			83
84			84
85			85
86			86


```

COMMON VAR
COMMON VAR
RIGHTMOST CHARACTER MASK
NO. CHARACTERS IN LABEL ARRAY
NO. SPACES BETWEEN PRINTER VERT GRIDS
TEMPORARY
BIAS TO CONVERT TO DISPLAY CODE

BAD1=0.0
BAD2=0.0
BAD3=0.0
NSCALE(1) = N1(1)
NHL=N2
NSBH=N3
NVL=N4
NSBV=N5
IF (NSCALE(1)) 10,80,10
10 NSCALE(2) = N1(2)
   NSCALE(3) = N1(3)
   NSCALE(4) = N1(4)
   NSCALE(5) = N1(5)
   IF (NSCALE(2)) 40,30,40
30 SCALE(2)=1.0
   GO TO 50
40 SCALE(2)=10.0**NSCALE(2)
50 IF (NSCALE(4)) 70,60,70
60 SCALE(4)=1.0
   GO TO 80
70 SCALE(4)=10.0**NSCALE(4)
80 DO 90 I=1,4
   IF (NP2(I)) 140,140,90
90 CONTINUE
   IF (NSCALE(3).GT.7) NSCALE(3)=7
   IF (NSCALE(5).GT.8) NSCALE(5)=8

C      CALCULATE SIZE OF GRAPH (NUMBER OF WORDS REQUIRED TO STORE IT)
C
C

```

```

87      LINES=NHL*NSBH+1
88      COLM1=NSBV*NVL
89      COLS=COLM1+1
90      IF (COLS.GT.LIMIT) GO TO 140
91      WORDS=(COLS+KORE-1)/KORE
92      ISIZE=LINES*WORDS
93
94      C      BLANK OUT ARRAYS WHICH WILL CONTAIN GRID SYMBOLS FOR LABELED AND
95      C      UNLABELED HORIZONTAL LINES
96      C
97      C      DO 100 I=1,24
98      C      100 IDASH(I)=10H
99      C      NGT9=NSBV
100      C      DO 120 I=1,10
101      C      IF (NGT9-10) 110,130,130
102      C      110 NGT9=NGT9+NSBV
103      C      120 CONTINUE
104
105      C      MODIFY VARIABLE FORMATS MAT1 AND MAT3 WHICH WILL BE USED BY PLOT4
106      C      TO PRINT THE GRAPH
107      C
108      C      130 NT=NGT9-9
109      C      IVT(1)=NT/100
110      C      IVT(2)=(NT-IVT(1)*100)/10
111      C      IVT(3)=NT-(IVT(1)*100+IVT(2)*10)+IZ
112      C      NT=((IVT(1)+IZ)*10000B+(IVT(2)+IZ)*100B+IVT(3))*M5
113      C      MAT3(2)=MAT3(2).AND..NOT.M2
114      C      MAT3(2)=MAT3(2).OR.NT
115      C      MAT1(2)=MAT1(2).AND..NOT.M1
116      C      MAT1(2)=MAT1(2).OR.(NSCALE(3)+IZ)*M3
117      C      LAB=SHIFT(NSCALE(5)+IZ,12)
118      C      MAT3(1)=MAT3(1).AND..NOT.M4
119      C      MAT3(3)=MAT3(3).AND..NOT.M4
120      C      MAT3(1)=MAT3(1).OR.LAB
121      C      MAT3(3)=MAT3(3).OR.LAB
122      C
123
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125  C      FILL IN ARRAYS WHICH WILL CONTAIN GRID SYMBOLS FOR LABELED AND
126  C      UNLABELED HORIZONTAL LINES
127  C
128  C      CALL DASPXXX
129  C      RETURN
130  C      140 BAD1=1.0
131  C      PRINT 150
132  C      RETURN
133  C
134  C      150 FORMAT ( 16H BAD INPUT PLOT1)
135  C      END
1      SUBROUTINE DASPXXX
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C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

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PLACE PLACES CHARACTERS (MCHAR) IN AN ARRAY (IARRAY)

MSHIFT      SHIFT COUNT TO GET PROPER CHARACTER LOCATION IN WORD
MTIMES      NUMBER OF TIMES TO INSERT THE CHARACTER
MSKPCH      NUMBER OF POSITIONS TO SKIP BETWEEN INSERTS
MCHAR       CHARACTER TO BE INSERTED

I=1
DO 30 J=1,MTIMES
  INSERT CHARACTER IN WORD
  IARRAY(I)=(IARRAY(I).AND.SHIFT(MASK,MSHIFT)).OR.SHIFT(MCHAR,MSHIFT
1)
SKIP MSKPCH CHARACTERS
DO 20 K=1,MSKPCH
  MSHIFT=MSHIFT-6
  IF (MSHIFT) 10,20,20
10 I=I+1
  MSHIFT=54
20 CONTINUE
30 CONTINUE
  RETURN
END
SUBROUTINE PLOT2 (IMAGE,LMT,P2,P1,P4,P3)

PLOT2 PREPARES THE GRID,EXAMINES THE MAXIMUM AND MINIMUM VALUES
OF THE ABSCISSA AND ORDINATE AND ESTABLISHES INTERNALLY A FORMULA
FOR COMPUTING THE LOCATION IN THE IMAGE REGION CORRESPONDING TO
THE POINT (X,Y)

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REAL LINPUNY
INTEGER WORDS, COLS, COLM1
DIMENSION IMAGE(1)
COMMON /COMPLOT/ NSCALE(5), NHL, NSBH, NVL, NSBV, XMAX, XMIN, YMAX, YMIN, I
1BCD, NDATA, IOMIT, NOBOT, NOORD, NOAB, VT(15), COLM1, COLS, LINES, WORDS, IDA
2SH(12), ISPACE(12), UNYPLIN, UNXPCOL, LINPUNY, CCLPUNX, MAT1(3), MAT2(2),
3MAT3(3), ISIZE, KORE, LIMIT, BAD1, BAD2, BAD3, I, J, K, MPC, NCHAR, NGT9, LAB
DATA NGT9, BAD1, BAD2, BAD3/10, 0, 0, 0/
DATA MAT1/10H(1X, R1, 2X, , 10HF8.3, 1X, 12, 4HA10)/
DATA MAT2/10H(1X, R1, 11X, 7H, 12A10)/
DATA MAT3/10H(8X, F9.3, , 10H14( 1X, , 10H F9.3))//
-----
(1X, R1, 2X, F8.3, 1X, 12 A10)
(1X, R1, 11X , 12A10)
(8X, F9.3, 14( 1X, F9.3))
-----
DATA MPC/77B/
DATA NHL, NSBH, NVL, NSBV/5, 3*10/, NOBOT, NOORD, NOAB/3*0/, COLM1, COLS, LI
1NES, WORDS, ISIZE, KORE, LIMIT/100, 101, 51, 11, 561, 10, 120/
DATA (IDASH(K), K=1, 11)/10*10H+-----, 1H+/
DATA (ISPACE(K), K=1, 11)/11*1H!//
DATA NSCALE/0, 1.0, 3, 1.0, 3/
IF (BAD1) 10, 10, 100
10 IF (ISIZE-LMT) 20, 20, 100
20 XMAX=P1
XMIN=P2
YMAX=P3
YMIN=P4
IF (XMAX-XMIN) 103, 100, 30
30 IF (YMAX-YMIN) 100, 100, 40
C
C
C
C
CALCULATE SCALING FACTORS TO BE USED TO CONVERT RAW DATA POINTS
TO GRID POSITIONS
C
C
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C

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43 UNXPCOL=(XMAX-XMIN)/COLM1
44 UNYPLIN=(YMAX-YMIN)/(LINES-1)
45 LIMPUNY=(LINES-1)/(YMAX-YMIN)
46 COLPUNY=CCLM1/(XMAX-XMIN)
47 K1=-WORDS
48 IG=0
49
50 PLACE GRID LINES IN GRAPH IMAGE
51
52 DO 90 I=1,LINES
53 K1=K1+WORDS
54 IF ((I-IG+NSBH)-1) 70,50,70
55
56 50 IG=IG+1
57 DO 60 K=1,WORDS
58 60 IMAGE(K+K1)=IDASH(K)
59 GO TO 90
60 DO 80 K=1,WORDS
61 80 IMAGE(K+K1)=ISPACE(K)
62 90 CONTINUE
63 RETURN
64 100 BAD2=2.0
65 PRINT 110
66 RETURN
67
68 110 FORMAT ( 16H BAD INPUT PLOT2)
69 END
70 SUBROUTINE PLOT3(IMAGE,KAR,X,Y,NK)
71
72 PLOT3 PLACES A SPECIFIED BCD PLOTTING CHARACTER IN THE APPROPRIATE
73 POSITION(S) CORRESPONDING TO THE GIVEN VALUES(S) OF (X,Y)
74
75 REAL LIMPUNY
76 INTEGER WORDS,COLS,COLM1
77 COMMON /CCMPLOT/ NSCALE(5),NHL,NSBH,NVL,NSBV,XMAX,XMIN,YMAX,YMIN,I
78 1BCD,NDATA,IOMIT,NOBOT,NOORD,NOAB,VT(15),COLM1,COLS,LINES,WORDS,IDA
79 2SH(12),ISPACE(12),UNYPLIN,UNXPCOL,LIMPUNY,COLPUNY,MAT1(3),MAT2(2),
80 3MAT3(3),ISIZE,KORE,LIMIT,BAD1,BAD2,BAD3,I,J,K,MPC,NCHAR,NGT9,LAB
81 DIMENSION X(1), Y(1), IMAGE(1)
82 IF (NK) 90,90,10

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14 IF (BAD2) 20,20,90
15 IBCD=SHIFT(KAR,6).AND.MPC
16 NDATA=NK
17
18 POSITION NDATA CHARACTERS IN PLOT IMAGE
19
20 DO 80 I=1,NDATA
21 K1=((YMAX-Y(I))*LINPUNY)+1.5
22 IF (K1-LINES) 30,30,70
23 IF (1-K1) 40,40,70
24 K2=((X(I)-XMIN)*COLPUNX)+1.5
25 IF (1-K2) 50,50,70
26 IF (K2-COLS) 60,60,70
27 IS=(K2+KORE-1)/KORE
28 MOVE=(KORE*IS-K2)*6
29 IS=IS+(WORDS*(K1-1))
30 IMAGE(IS)=IMAGE(IS).AND..NOT.SHIFT(MPC,MOVE).OR.SHIFT(BCD,MOVE)
31 GO TO 80
32
33 GO HERE FOR A POINT WHICH IS OFF THE PLOTS SCALE
34
35 70 BAD3=-3.0
36 80 CONTINUE
37 90 RETURN
38 90 BAD3=3.0
39 PRINT 100
40 RETURN
41
42 100 FORMAT ( 28H NO PLOT2 OR BAD INPUT PLOT3)
43 END
44 SUBROUTINE PLOT4(IMAGE,NN,LABEL)
45
46 PLOT4 PRINTS THE IMAGE OF THE COMPLETED GRAPH. A LABEL FOR THE
47 ORDINATE IS PRINTED VERTICALLY (ONE CHARACTER PER LINE) AT THE
48 LEFT EDGE OF THE PAGE. VALUES OF THE ABSCISSA AND ORDINATE ARE
49 PRINTED AT THE GRID LINES OUTSIDE THE BOTTOM AND LEFT EDGE OF
50 THE GRAPH
51

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8	
9	
10	REAL LINPLNY
11	INTEGER WORDS,COLS,COLM1
12	DIMENSION LABEL(1), IMAGE(1), SCALE(5)
13	COMMON /CCMPLOT/ NSCALE(5),NHL,NSBH,NVL,NSBV,XMAX,XMIN,YMAX,YMIN,I
14	1BCD,NDATA,IOMIT,NOBOT,NOORD,NOAB,VT(15),COLM1,COLS,LINES,WORDS,IDA
15	2SH(12),ISPACE(12),UNYPLIN,UNXPCOL,LINPUNY,COLPUNX,MAT1(3),MAT2(2),
16	3MAT3(3),ISIZE,KORE,LIMIT,BAD1,BAD2,BAD3,I,J,K,MPC,NCHAR,NGT9,LAB
17	EQUIVALENCE (NSCALE,SCALE)
18	IF (BAD1+BAD2+BAD3) 20,20,10
19	10 PRINT 180
20	RETURN
21	20 J=LINES
22	30 IF (NOBOT) 30,40,30
23	40 J=J-1
24	40 NCHAR=NN
25	K2=0
26	K4=0
27	DO 130 I=1,J
28	LOCATE,MASK OFF AND STORE THE NEXT CHARACTER IN THE ORDINATE LABEL
29	
30	IF (I-NCHAR) 50,50,80
31	50 K1=(I+KORE-1)/KORE
32	IF (K1-K2) 70,70,60
33	60 K2=K1
34	LAB=LABEL(K2)
35	70 LAB=SHIFT(LAB,6)
36	GO TO 90
37	80 LAB=1H
38	90 K3=K4+1
39	K4=K4+WORDS
40	IF (MOD(I,NSBH)-1) 120,106,120
41	100 IF (NOORD) 120,110,120

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C      CALCULATE THE VALUE OF THE ORDINATE TO BE PRINTED AT THE GRID LINE
C      OUTSIDE THE LEFT EDGE OF THE GRAPH
C
110  VALUE=(YMAX-(I-1)*UNYPLIN)*SCALE(2)
    PRINT MAT1, LAB,VALUE,(IMAGE(K),K=K3,K4)
    GO TO 130
120  PRINT MAT2, LAB,(IMAGE(K),K=K3,K4)
130  CONTINUE
    IF (NOAB) 170,140,170
C
C      CALCULATE THE VALUES OF THE ABSCISSA TO BE PRINTED AT THE GRID
C      LINES OUTSIDE THE BOTTOM OF THE GRAPH
C
140  J=0
    I=1
150  J=J+1
    VT(J)=(XMIN+FLOAT(I-1)*UNXPCOL)*SCALE(4)
    I=I+NGT9
    IF (I-COLS) 150,150,160
C
C      FOLLOWING MHS CODE INSERTS PROPER REPEAT FACTOR IN MAT3
C
160  LAB=10000000000000B*(MOD(J-1,10)+100B*((J-1)/10)+33338)
    MAT3(2)=(MAT3(2).AND.7777777777777B).OR.SHIFT(LAB,12)
    PRINT MAT3, (VT(I),I=1,J)
170  RETURN
C
180  FORMAT ( 13H NO PLOT MADE)
    END

```

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